WOODWORKING MACHINERY

ITS

RISE, PROGRESS, AND CONSTRUCTION

WITH

HINTS ON THE MANAGEMENT OF SAW MILLS AND
THE ECONOMICAL CONVERSION OF TIMBER

A COMPANION VOLUME TO 'SAW MILLS, THEIR ARRANGEMENT AND MANAGEMENT

BY

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'A HANDBOOK FOR STEAM USERS' ETC.

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PREFACE.

> Content if hence th' unlearn'd their wants may view,
> The learn'd reflect on what before they knew.—POPE.

THE FOLLOWING PAGES, written in the spare hours of a busy life, attempt to give an account of the rise and progress of what is now in this country an important branch of engineering. Although wood is employed in the constructive arts more largely than any other substance, its conversion by machinery is of comparatively modern origin, and therefore very few books or treatises have been written on the subject. The aim of the Author has been to combine, as far as possible, the historical with the practical. In the first portion of the book, in addition to notes on design and construction, the names of the chief inventors and pioneers in wood-working machinery will be found; the latter part of the work is devoted entirely to practical and technical details.

The illustrations are confined to the designs of English, French, and American engineers, the machines constructed by other nations being, as a rule, based on these models.

The adaptation of machinery to common uses is, without doubt, increasingly necessary to the commercial prosperity and progress of a nation, and has been exemplified by the success of American competition in some branches of manufacture. This can in a measure be accounted for by the low patent fees and high rates of wages in vogue in that country, thus encouraging inventors to perfect the smallest details in their machine construction which tend either to lessen the cost of production, improve the quality, or increase the range of the work performed. From a somewhat extended practical experience of the subject treated on, the Author trusts that what he has written may afford some fresh information, and prove of service to the engineer and student. In that case his end will have been attained.

NOTE TO THE THIRD EDITION.

SINCE the last edition of this book was issued great all-round progress has been made in the economical conversion of wood, notably by the extended introduction of log band and band re-sawing machines, chain mortising machines, and many others for special purposes, such as the manufacture of wood wool, producer gas from wood waste, &c. Many improvements have also been made in the constructional details of the machines, the chief of which is the large employment of ball, roller and ring oiling bearings, which have reduced the working friction to a minimum. Tool rooms in saw mills are now worked on a more scientific basis, and for information in this connection the Author would refer readers to his companion volume, 'Saw Mills, their Arrangement and Management.'

The Author has taken the present opportunity of printing a series of new illustrations which will be found to embody the most recent designs in wood working.

15 SUTTON COURT ROAD, CHISWICK,
August 1914.

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RULES AND TABLES.

Rules for Calculating Speeds of Shafts and Diameters of Pulleys.

The speed of the driver and the diameter and speed of the driven being given, to find the diameter of the driver.

PROBLEM 1.

Rule.—Multiply the diameter of the driven by its speed, and divide the product by the speed of the driver; the quotient will be the diameter of the driver.

PROBLEM 2.

The speed of the driven and the diameter and speed of the driver being given, to find the diameter of the driver.

Rule.—Multiply the diameter of the driver by its speed, and divide the product by the speed of the driven; the quotient will be the diameter of the driven.

PROBLEM 3.

The diameter of the driven being given, to find its number of revolutions.

Rule.—Multiply the diameter of the driven by its revolutions, and divide the product by the diameter of the driven; the quotient will be the number of revolutions of the driven.

We give herewith tables of the specific cohesion and strength and the resistance of wood to pressure as calculated by Professor Wallace.

Specific Cohesion and Strength of Wood.

Alder	1·506
Ash	from 1·804 to 1·274
„ red, seasoned	1·899
„ white „	1·509
Bay	from 1·547 to 1·085
Beech	1·880
Cedar	0·528
Chestnut, a century in use	1·291
Citron	from 1·357 to 0·8[illegible]8
Cypress	„ 0·732 „ 0·542
Elder	1·086
Elm	1·132
Fir	from 1·380 to 0·879
„ pitch pine	„ 1·398 „ 0·380
„ strong red	1·172
„ Memel, seasoned	1·154
„ Russian	from 1·062 to 0·963
„ American	0·942
„ yellow deal	0·90[illegible]
„ white „	0·455
„ Scotch	0·711
„ Scotch, seasoned	from 0·837 to 0·745
Lance wood	2·021
Larch	1·177
Lemon	1·004
Mahogany, Spanish	1·283
Maple, Norway	1·123
Mulberry	1·492
Oak	from 1·891 to 0·955
„ English	„ 1·085 „ 0·936
„ „ seasoned	1·50[illegible]
„ French	from 1·060 to 0·960
„ „ seasoned	„ 1·559 „ 1·363
„ Baltic „	1·211
„ American white	1·009
„ Danzic	0·818
Plum	from 1·357 to 1·205
Pomegranate	1·221 „ 0·882

Specific Cohesion and Strength of Wood—continued.

Poplar . . . . . . from	0·705 to 0·488
Teak, Java, seasoned	1·509
„ Pegu „ „	1·400
„ Malabar	1·305
Willow . . . . . . from	1·375 to 0·809

Resistance of Wood to Pressure.

In this table the experiments are with cubes of 1 inch on the edge.)

	Lbs.
American pine	1,606
Elm.	1,284
English oak	3,860
White deal	1,928

Table of Specific Gravities of Seasoned Timber, by W. Templeton.

	Specific Gravity	Pounds Cubic Feet	Cubic Feet =1 Ton		Specific Gravity	Pounds Cubic Feet	Cubic Feet =1 Ton
Alder . . .	736	46	48¾	Larch . . .	530	31	72¼
Apple tree . .	793	49½	45¼	Lemon tree . .	704	44	51
Ash	845	52	43	Lignum vitæ . .	1,336	83½	26¾
Beech . . .	852	53¼	42	Lime tree . .	760	47½	47¼
Birch, English . .	792	49½	45¼	Logwood . . .	913	57	39½
„ black, American . .	648	40½	55	Mahogany, Spain .	720	45	50
Blackwood, Australian . .	662	41½	54	„ Honduras	560	35	64
Blue gum . . .	1,100	68¾	32½	Maple . . .	750	47	47½
Box, French . .	1,328	83	27	Oak, English . .	934	58	38½
„ Dutch . .	912	57	39	„ American. .	672	42	53½
Cedar, American .	561	35	64	„ African . .	944	59	38
„ Sydney . .	560	34½	64	Orange tree . .	705	44	49¾
„ Canadian .	910	57	39¼	Pear tree . . .	660	41	54½
Cherry tree . .	715	45	50	Pine, pitch . .	736	46	48¾
Chestnut . . .	610	38	59	„ red . .	672	42	53
Cork . . .	240	15	149	„ white . .	456	28½	78½
Cowrie pine, New Zealand .	512	32	70	„ yellow . .	448	28	80
Crab tree . . .	768	48	46½	Poona . . .	640	40	85
Ebony, Indian . .	1,208	75½	29	Poplar . . .	384	24	93¼
„ American .	1,331	83	27	Plum tree . . .	785	49	45¾
Elm	673	42	53	Red gum, Australia .	901	56	40
Hawthorn . . .	610	38	59	Rosewood, black .	1,280	80	28
Holly and hornbeam	760	47½	47¼	Sycamore . . .	624	39	57¼
Iron bark, Australian	1,233	77	29¼	Teak	750	46	48½
Laburnum . . .	920	57½	39	Walnut . . .	671	42	53½
Lance wood . .	1,023	64	35	Willow . . .	585	36½	61¼
				Yew, Spanish . .	807	50½	44¼
				„ Dutch . .	788	49¼	45

Composition of Woods.

Woods	Carbon	Hydrogen	Oxygen	Nitrogen	Ash
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Beech .	49·36	6·01	42·69	0·91	1·00
Birch .	50·20	6·20	41·62	1·15	0·81
Oak .	49·64	5·92	41·16	1·29	1·97
Poplar .	49·37	6·21	41·60	0·96	1·86
Willow .	49·96	5·96	39·65	0·96	3·37

Measurement of Timber.

In measuring standing timber the length is taken as high as the tree will measure 24 inches in circumference. At half this height the measurement for the mean girth of the timber in the stem of the tree is taken. One-fourth this girth is assumed to be the side of the equivalent square area. The buyer has generally the option of choosing any spot between the butt end and the half-height of the stem as the girding place. All branches, as far as they measure 24 inches in girth, are measured in with the tree as timber.

Proportions of Metals for the Production of Useful Alloys (W. Templeton).

	Copper	Tin	Zinc
Babbitt's . .	1	50	—
Bearings for machinery	16	2½	½
Bell metal for large bells	8	2	0
" " small "	16	5	0
Brass, hard	3½	1	0
" sheet .	3	0	1
" yellow .	2	0	1
" deep yellow .	1	0	2
Bronze . . .	4½	1	0
" . . .	9	1	0
Gun metal . .	11	2	0
" " . .	8	1	1
Muntz's metal . .	1½	0	1
Spelter copper for brass .	1	0	1
" " copper and iron	16	0	12
	Lead		
Glazier's solder . . .	3	1	0
Plumber's " . . .	1	1	0
Tinman's " . . .	2	1	0

Table of Mechanical Properties of the Materials of Construction.

	Weight of a Cubic Foot in Lbs.	S. Value of the Coefficient of Absolute Transverse Strength	Value of a Resistance to Crushing per Square Inch in Lbs.	Tenacity per Square Inch in Lbs.
Ash or beech	47–53	12,156	9,000	14,700
Box, dry	60		10,300	19,800
Brass, cast	525	18,000	10,304	18,000
Bricks	130	—	560–800	280
Brickwork	112	280–300		—
Chestnut	41	10,660	—	11,900
Clay	119			—
Coal	77–100	—	—	—
Copper, cast	549	19,600	—	19,000
Deals, red	36–43	9,3[illegible]2	6,586	—
„ spruce	21	9,900	6,293	—
Earth, rammed	99		—	
Elm	36	6,690	10,300	14,200
Fir, Riga	17	6,648	6,000	12,000
Glass, plate	153	9,400		9,400
Gold	1,203	—		
Granite	165			—
Gravel	120	—		
Iron, wrought	481	42,000	40,000	51,000
„ cast solid	[illegible]	39,000	115,000	20,000
Ivory	114	—	—	—
Lance wood	63	17,350	—	23,000
Larch	32	5,118	5,570	9,500
Lead	712	3,300	—	3,300
Mahogany, S.	50	11,500	8,200	19,000
Marble	164	—	6,060	[illegible]
Marl	118		—	—
Mercury	848		—	—
Mortar	107	50	—	50
Oak, E.	58	10,032	10,000	13,300
„ Dantzic	47	8,742	7,700	—
„ Canadian	54	10,596	—	—
Pine, pitch	41	9,792	6,790	7,800
„ red	48	8,016		7,800
„ American yellow	28	6,612	5,400	—
Poplar	23	—	—	6,016
Sand, river	117	—	—	—
Silver	644	—	—	—
Slate	180	2,600	—	12,000
Steel	486	100,000		100,000
Stone	120–170	1,100–2,360	6,000	—
Teak	41	14,772	12,000	12,460
Tin, cast	455	4,600	—	4,600
Walnut	41	—	7,227	8,460
Water	62	—	—	—
Zinc	439	7,000		7,000

APPENDIX

LOG BAND SAWING MACHINES.

Log band saws of the horizontal type are now generally preferred in this country, and they undoubtedly possess advantages over the vertical type, notably that they can be much more easily fixed, and the log fixed, adjusted, or examined with greater facility; the saws can also be more rapidly exchanged. Space forbids our going into the various points to be desired in their construction here, but we may say that two of the chief are that the main frame should be of massive construction with the metal so apportioned, that there is absolute freedom from vibration when the machine is running under a full load.

The saw wheels should combine strength with comparative lightness, be supported by double bearings, and be in absolute balance. The writer prefers that the faces of the saw wheels should be flat on the face or with the slightest possible round, as this permits the easier tensioning of the saws. Large band saw wheels are not now covered on the face, but the saw is run metal to metal.

Advanced machines are fitted with ball or roller bearings to the saw pulley spindles, which undoubtedly effect an immense saving in bearing friction, but owing to the great strain and suddenly applied loads put on the saw, it is important that they are provided with an ample factor of safety, and side or end thrust guarded against, as the writer has come across several cases of trouble in this connection.

Where electric current is cheap, machines can often be driven by electricity with advantage. The best practice is to couple the motor directly on to the driving spindle, as this keeps the saw up to its standard speed, and countershafts and belts—with their slip—are done away with. The travelling table can also be driven by a motor, but care must be taken that the motors selected are of ample power and can withstand overloads, or heating and other troubles may occur.

Owing to the quantity and quality of the work turned out and the saving effected in wood and power, log band saws for certain classes of work are gradually superseding vertical log and horizontal frames and rack circular saw benches, and we look for still greater developments in this connection, as the band saw, when properly made and worked, is undoubtedly one of the most valuable of all wood-working tools.

Much of the success of band sawing machines undoubtedly depends on the construction and working of the saws and full notes thereon will be found in the companion volume "Saw Mills, their Arrangement and Management."

Fig. 47 represents a distinctive type of horizontal log band mill manufactured by Thomas Robinson and Son, Limited, the patent variable speed feed gear and method of carrying the saw pulleys being perhaps the most notable features.

In general construction the machine is particularly massive, especially in the cored casting which forms the base. The vertical upright slides which carry the cross rail and saw pulleys are bolted to the base. Owing to the method of casting these upright slides or supports, the centres of the saw pulleys are kept as close together as possible, permitting the use of a short and rigid saw blade, and at the same time the rising and falling cross rail can be adjusted on the upright slides to take up for any wear. The elevating screws for the cross rail are protected in recesses formed in the upright slides, and so compact is the entire machine that the maximum size of log that can be cut is only limited by the distance between the upright pillars.

The saw pulleys are mounted on heavy steel shafts turned to a taper to receive them. They are bored to suit the shafts, and are secured by a lock-nut on a fine thread screw. The pulley shafts are of high grade steel, and run in long self-aligning bearings which are oil-retaining and dust-proof, and have large oil reservoirs, requiring the minimum of attention. Roller bearings are being fitted latterly, and bid fair to replace the old style bearing entirely.

The cross rail which carries the saw pulley bearings is a single casting, held at either end by long adjustable slides, and supported by large diameter screws from the connecting rail at the top of the upright pillars, the weight being taken on ball thrust bearings. The movable saw pulley bearings rest on flat slides, and are not over-hung, and this, combined with a sensitive saw-straining device, enables saws of very thin gauge to be used, thereby reducing saw kerf.

The saw straining device is extremely sensitive, and can be set to give a suitable amount of strain for saws of different gauges, by moving a weight having a spring cushioning device. Any variation due to the expansion and contraction of the saw blade whilst working is instantly and automatically taken up.

The tilting and cross lining adjustments to the saw pulleys are independantly controlled, the latter being specially convenient for the sawyer, and provides an exceedingly quick method of correcting the blade on the face of the pulleys, by merely moving a hand lever. The centres of the saw pulleys can be altered to suit different lengths of blade.

The saw guides move on a transverse slide to suit logs of varying widths. They are firmly locked when in position, and have provision for preventing the sawdust being carried on to the pulleys.

The feed gear is self-contained on a cast-iron baseplate placed at the side of the machine, and the log carriage is started, stopped, or reversed at a high speed by a single lever. A single lever also raises or lowers the cross rail and saw pulleys, and the depth of cut is shown on a scale which has a separate adjustment for gauging the exact depth of board to be cut, no matter at what height the saw blade is above the top of the log carriage.

The patient variable speed gear is positive in its action, and consists of a heavy V belt running between two pairs of expanding cones. This is claimed to be an improvement on the friction disc, the latter being limited in its transmission of power. The rate of feed with the cones can be varied at will whilst the machine is running.

The log carriage runs on planed rails fixed to the beams of the mill floor, and bolted direct to the base of the machine itself, so that the position of the log at the point of cutting is self-contained within the machine.

Fig 48 represents a horizontal log band mill by W. B. Haigh, Dunbar and Co., Limited. The whole of the machine, together with the feed and controlling gear, is mounted upon a massive bedplate, no part whatever being below the floor level.

The cross frame carrying the bearings, shafts and saw pulleys has positive and variable rising and falling motion on the large diameter pillars by screws, by power and by hand.

The bearings are claimed as one of the most important features of this machine, being of the patent combination roller, ball thrust and recoil type, and are guaranteed for a period of three years.

One of the saw pulleys is adjustable to track the blade to its correct position, and has a slight horizontal adjustment for lining up.

The knife-edge saw straining device is operated by a compound weighted lever, automatically compensating for expansion and contraction in the saw blade.

The anti-friction saw guides are adjustable by hand-wheel rack and pinion.

The table is built of rolled steel girders with heavy cast-iron cross-rails carrying the dog boxes.

It has positive feed by rack and pinion, and the friction feed arrangement is instantly variable from about 8 to 160 feet lineal per minute, and has an accelerated return motion of 250 feet per minute. Speed of saw blade 8,600 feet per minute.

Fig. 49 represents a band resawing machine by A. Ransome and Co., Limited. The main frame is of massive design to withstand the vibration of working.

The rims and centres of the saw pulleys are of tough cast iron and are turned all over, accurately balanced and fitted with wrought steel spokes which are staggered.

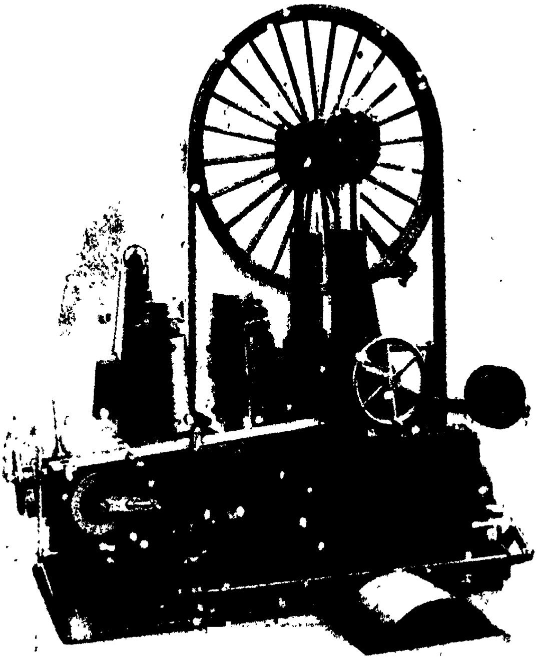

FIG. 46. 60-INCH BAND RE-SAW.

The saw blade and pulleys run metal to metal. The saw pulleys are fitted on turned steel shafts of large diameter and are mounted in either ball journal or roller bearings with dust-proof housings according to the size of the machine.

The feed gear consists of six vertical rollers, two pairs of which are of large diameter and all are driven. One pair of rollers are of smaller diameter and are placed close up to the cutting edge of the saw to ensure of the wood being held firmly.

The rollers are arranged to cant for cutting feather-edged boards if required and the rate of feed is readily variable up to 150 feet per minute.

The tension apparatus is arranged to work on a knife edge and can be readily adjusted to suit saws of different widths and gauges by shifting a weight along a horizontal lever.

The feed is fitted with a self-centring apparatus, by which deals or boards of varying thicknesses can be cut down the centre without further adjustment, and the rate of feed can be changed if desired whilst the saw is cutting.

Adjustable saw guides are fitted immediately above and below the wood and the bottom saw heel is made of increased weight to prevent overrunning.

Average speed of saw blade 7,000 feet per minute.

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WOOD-WORKING MACHINERY

CHAPTER I.

INTRODUCTORY.

Wood in its various forms enters, perhaps, more largely than any other substance into the industry of the nation, and its economical and rapid conversion from forest trees into articles of general utility cannot be but one of paramount importance. I can scarcely help thinking that sufficient interest has hardly been given by scientific men to this very important branch of engineering, whilst, on the other hand, improvements in the munitions of war, for instance, have been carried to the highest degree of perfection. When we come to consider the endless uses—in shipbuilding, railway carriage works, coachbuilding, joinery works, builders' establishments, &c.—that wood in its varied forms is put to, the importance of the subject will, perhaps, more readily strike us. Wood conversion by machinery has doubtless during the last twenty years made gigantic strides, but still there remains ample scope for further progress in this direction. The chief hard woods used in this country are oak, ash, mahogany, teak, and elm; and of the resinous woods, red pine from Norway, Sweden, and Russia; Memel, Dantzig, and Riga fir, from Russia and Prussia; yellow pine, pitch pine, and cedar. Other ornamental woods are, however, largely used for decorative purposes. Although one of the most important branches of engineering, wood-working machinery is one of the most modern; there is no doubt, however, that the conversion of wood by means of saws, axes, &c., was known some thousands of years back, and is spoken of in ancient Egyptian, Grecian, and Hebrew history; but very few records are left us concerning their origin in this country. We must turn to the eighteenth century for any accurate information as to absolute *machinery*, in the true sense of the word, although, doubtless, apparatuses of different kinds were in use to facilitate hand labour before this date.

First and foremost among the pioneers of wood-working machinery must be placed Sir Samuel Bentham, whose patents in the years 1791 and 1793 are truly remarkable examples of inventive genius, and fully illustrate the old adage, 'There is nothing new under the sun.' In these specifications the principles involved in many of the most important machines at present in use are claimed, and set forth in the clearest and tersest manner, affording a wonderful illustration of how a patent could be drawn in those days. The following may be named as some of the inventions included in this remarkable specification:—Planing machines with rotary cutters, *to cut on several sides of the wood at once*; veneer-cutting machine, horizontal stone saws, moulding and recessing machine, bevel sawing machine, saw-sharpening machine, tenon-cutting by means of circular saws, and many kinds of rotary and boring tools. Many of the principles set forth in Bentham's specifications have been the subjects of a number of patents during the present century, or, I may say, during the last few years, but it is my opinion that several of these patents differ very little indeed except in matter of detail from Bentham's ideas in 1793. I do not intend here to enter further into the early history of wood-working machinery, as the data at my disposal are both scant and somewhat unreliable, but I purpose, when considering the different classes of machines, to add such notes of their origin as I may consider instructive and interesting. It is my intention to confine myself in these pages chiefly to my experience of English practice, illustrating the same with woodcuts of some of the latest examples of the most eminent makers, and explaining them as concisely and, I trust, as *practically*, as possible. I shall, however, as occasion may arise, touch on American and Continental makes when of interest.

Till within the last thirty years, wood-working machinery in this country must be considered to have been in a very crude state, but of late great impetus has been given to it by the constant battles between capital and labour. The great cost and, in some cases, the inferior quality of work turned out by hand, have rendered the increasing introduction of labour-saving machinery absolutely necessary, to keep pace with the general progress of the times. The introduction of this class of machinery has not, however, lessened, but rather raised, the wages of skilled artisans, as it is found the cheaper production creates the greater demand.

CHAPTER II.

CIRCULAR SAW BENCHES.

WITH the exception, perhaps, of the wedge and the axe, the saw can lay claim to being the most ancient instrument for the conversion of wood, and it is certainly by far the most important. Its earliest history, however, from the lapse of ages, is involved in obscurity. Representations of saws are said to have been discovered on some of the most ancient of Egyptian monuments. This, taken in connection with the many times the saw is mentioned in Holy Scripture and other ancient histories, seems to conclusively prove that the saw was known many thousands of years ago. What it was constructed of, however, there are no records to show. Ancient Grecian historians variously ascribe its invention to Dædalus, Perdix, and Talus,[1] and the inventor, whoever he was, was inscribed in their mythology, with a place in which, among their gods, they honoured the greatest benefactors of the earliest ages. Talus is said to have formed his first saw from the jaw-bone of a snake. Perdix, we are told, used the backbone of a fish for a like purpose. The saws of the Grecian carpenters had a similar form to ours in use at present, as shown by a painting still preserved among the antiquities of Herculaneum. Two genii are represented at the end of a bench; the piece of wood which is to be sawn through is secured by cramps. The saw with which the genii are at work has a perfect resemblance to our frame saw. It consists of a square frame, having in the middle a blade, the teeth of which stand perpendicular to the plane of the frame. The arms in which the blade is fastened have a similiar form to those we now use.

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[1] See Beckmann's *History of Inventions*.

It is recorded that saw mills driven by water or wind were erected in Germany as early as the fourteenth century; this is, however, very much open to doubt, Stetten says in his work ('Kunst- und Handwerks-Geschichte der Stadt Augsburg,' 1779) that saw mills were erected near Augsburg in the year 1337; but what the machinery consisted of, or by what means it was driven, there is nothing to show. It is also recorded that saw mills were in existence at the following places at the dates named:—Breslau, 1427; Holstein, 1545; Lyons, 1555; Ratisbon, 1575; and in Norway in the year 1530. The first mill erected in Holland was at Saardam in 1596, and in Sweden about 1653.

The first saw mill in England of which we have any record was erected by a Dutchman near London about the year 1663, but was the occasion of so much riot that it had to be abandoned. This was also the case with a mill erected by one James Stansfield in 1768, as it was torn to pieces by the mob. Wind was the motive power used by Stansfield, and it seems that he and others, aided by the Government, erected mills in various parts of the country about this time, which were allowed by the populace to continue working. The straight saw or mill web was doubtless in use many years in Holland

and Germany before the circular saw was known. The circular saw is said to have originated in Holland in the sixteenth or seventeenth century, but there is nothing to show who was the inventor. One of the earliest records of its use in this country is contained in the patent specification of Samuel Miller, of Southampton, granted in the year 1777, in which he claims 'an entirely new machine for more expeditiously sawing all kinds of wood, stone, and ivory; and the saws used are of a *circular figure*.' The motive power employed was a horizontal windmill. He also claimed an arrangement for bringing the timber up to the saws when in motion; in point of fact, it may be considered our present rack saw-bench in embryo. Bentham, in his specification of 1793, claims also various improvements in sawing machines, including 'crown saws, taper gauge, grooving table, adjustment of saws in benches, &c.

In the year 1805, Brunel took out a patent for 'improvements in machinery for sawing timber,' with arrangements for veneer cutting, &c.; he also about this time fitted up the Government dockyard at Portsmouth with sawing machinery, including both reciprocating and circular saws. It was considered at that day the most complete machinery in the country. We have before us an engraving of one of these machines, especially adapted for preparing the rough timber for block-making; the elm trees of which the blocks were formed were cut into proper lengths by two cross-cutting saws, one of which is a reciprocating and the other a circular saw. This combination of straight and circular saws for this special work would not do discredit to a designer even of the present day. Of course some of its details appear to us somewhat crude; but, as showing early efforts in introducing wood-working machinery into this country, I think it of sufficient general interest to append herewith a short general description:-

'The tree subjected to the action of the cross-cutting reciprocating saw is placed on a long frame or bench, raised a little above the floor, on the end of which is a frame composed of vertical posts and a cross-beam. Through this frame the end of the tree is drawn, by a capstan working in the middle of the room upon a vertical shaft, turned by a steam engine. The end of the timber projects as much beyond the front of the frame as the part intended to be cut off, and is fastened from rolling sideways by a lever, which presses upon it and holds it down. The saw is a straight blade, fixed into a wooden handle at each end to lengthen it. One of these handles is connected by a joint to the upper end of a lever, bent at right angles and having the centre beneath the floor. The horizontal arm of the lever is connected by a spear rod with the crank on the end of a spindle near the ceiling of the room, the motion of which is regulated by a fly wheel. By this means the saw has a reciprocating motion from right to left nearly in a horizontal position, and exactly across the log that is to be cut, resembling in its action the carpenter's hand saw. The teeth of the saw are, of course, on the lower side of the blade, and it acts entirely by its own weight. The machine, being at rest, is prepared for work by fixing the log in the frame by the lever, so that the surface of the frame intersects the log at the place it is intended to be cross-cut. The saw, which was before lifted up by its handle to be clear of the log, is now suffered to rest upon it in the place where the cut is to be made; and to guide it in first setting-in, the back of the saw is received in a saw kerf, made in the end of a piece of board, which is attached to the frame over the saw, but slides up and down, to reach it at any height, according to the thickness of the log. The machinery is then put in gear, which causes the saw to reciprocate horizontally across the tree, and thus by its own weight cuts it through. As the saw gets into the tree, it quits the guide above mentioned, which becomes less necessary as the saw goes deeper, a saw having no tendency to alter its course when cutting across the grain.

'The circular cross-cutting saw, which is employed for the same purpose, is more novel in its construction. The spindle is so mounted as to move in any direction parallel to itself, the saw continuing in the same plane. By this means it can be applied to any part, so that it will divide trees much larger than could otherwise be done by it. It is more expeditious and accurate in its performance than the one above described, for which reason the preference is always given to it in all cases where the size of the tree is not too great for its application.'

What is now known as the American rack bench is really of English origin. In the year 1824 letters patent were granted to Messrs. Sayner and Greenwood for 'improvements in sawing machinery,' the chief of which was the use of two circular saws of small diameter placed one above the other, but with their peripheries revolving in the same line, in lieu of one saw of large diameter for breaking down heavy timber. The timber rested upon horizontal rollers, and was guided to the saw by vertical rollers. The feed was given to the log by means of a grooved feed roller, acted on by a pressure roller and weighted lever. They also claimed the use of several circular saws on one spindle, divided by suitable collars for converting timber into planks, with other saws placed on vertical spindles, and working horizontally for cutting the planks into scantlings at the same time. A third improvement consisted in cramping a series of circular saws closely together, and using them for reducing dye woods to powder, instead of the usual method of rasping or chipping. In the same year (1824) Mr. Robert Eastman, of Brunswick, Maine, U.S.A., patented some improvements in the construction of circular saws. These consisted chiefly in the introduction of a limited number of 'sectional' or 'false' teeth. Instead of a series all round the periphery of the plate, as is usual in ordinary circular saws, four cutting sections of two teeth are placed at equal distances on the periphery of the plate, and projecting from it. In addition to these teeth, cutters were fixed on the saw plate nearer to the centre, and were arranged for surfacing up the plank after it was cut. One of the novelties of this patent was the method employed for converting the log into boards, as the plan pursued was to cut from the circumference or exterior of the tree towards the centre, and not right through the tree, as is usually the case. In favour of this method it was urged that planks, staves for casks, &c., cut in this manner possessed more durability, strength, and elasticity than those cut in the ordinary way. The log to be operated on was made to revolve between iron centres, which it did after each succeeding cut of the saw, thus bringing the whole circumference of the log under its action. The saw spindle or shaft was made of cast iron, and ran upon friction rollers, supported by stands on the floor. The whole of the movements of the machine were self-acting, and a series of feather-edged boards of uniform thickness were cut all round the log, having their thin-edged sides attached to the centre piece; the log being big enough, a second series of boards could be cut in a like manner. The teeth employed were in the form of a hawk's bill, and the inventor claimed that the eight teeth used were driven with one-quarter the power than with an ordinary circular saw. This statement we cannot in any way agree to, and whatever was gained in the shape of power was more than lost by the excessive waste. The whole arrangement of the machine, however, reflects the greatest credit on its designer. The rate at which the saw was speeded to run was from ten to twelve hundred revolutions per minute.

Small circular saws for cutting the teeth of watch and clock wheels are reported to have been in use in the time of Dr. Hook. Letters patent were granted to Maudslay for 'improvements in mounting and lubricating circular saws' early in this century; also to one Charles Hammond, of London, for 'improvements in sawing and planing wood;' but from, say, the year 1810 to 1835 this branch of engineering appears to have remained almost at a standstill in England. Even America, with little or no iron and less general resources, made far greater progress than ourselves, a number of patents being taken out for inventions and improvements in curvilinear sawing for ships' timbers, mitre-cutting saws, barrel saws, &c., of which little or nothing was known in this country.

However, about the year 1836 Mr. John McDowall, of the Walkinshaw Foundry, Johnstone, near Glasgow, came prominently forward with some most ingenious novelties and improvements in sawing and planing machinery; previously, however, to 1836 he had erected several planing and other machines, in Manchester and elsewhere. These planing machines were made from the designs of Mr. Malcolm Muir, of Glasgow, to whom a patent was granted in the year 1827. We shall take occasion to notice them elsewhere. Some years later Mr. McDowall patented a high-speed tension sawing machine, and he also invented and erected a number of cross-cutting and other machines for the Government at Woolwich Arsenal. One of these, a traversing cross-cut circular saw bench, possesses such novel driving and other arrangements that I think it fully deserving of further notice, if space permitted. The saw itself was about 7 feet in diameter, the largest yet made from one solid piece of cast steel. The driving gear was a great novelty, the saw spindle being totally unconnected with the actuating power; the motion was communicated to the saw through two frictional cones of buff leather embracing the saw on either side, and running at a high speed. With this arrangement, the whole of the saw up to the cones was available for cutting, there being no pulleys in the way of the timber, as there are when saws for cross-cutting are driven in the usual way. The saw ran at 300 revolutions per minute, and by a very ingenious arrangement could be made to travel the whole length of the mill, some 70 feet; and being placed below the ground could also be raised above or depressed below the floor line at pleasure. In fact, the whole machine did infinite credit to its designer.

In connection with improvements in circular saw benches a patent was secured by Orlando Child, of Granville, Ohio, U.S.A., in the year 1850. He claimed chiefly the introduction into heavy saw benches of a spring attached to the frame, to prevent the end play of the saw spindle at the same time yielding to any great pressure from the springing of the log, and thus preventing any undue friction, and doing away also with the collars usually employed for preventing the end play of the spindle. In addition to the ordinary circular saw employed, he also mounted a second above it in a swinging frame, which could be set at any point forming part of a circle struck from the main saw spindle, and could operate with the main saw in cutting through a log at any angle desired.

A few years previous to our International Exhibition of 1851, Mr. Coulson, of York, England, introduced into this country various American ideas. Mr. William Furness, of Liverpool, also manufactured and patented a number of machines, from American models. A few years further on, Mr. Samuel Worssam, of London, brought out several machines, including a very complete deal frame, with improved silent feed, for which a patent was secured by him. At the Exhibition of 1851 a number of American wooden-framed machines were exhibited, which seems to have opened the eyes of some of our engineers, as from this date the progress and development of this branch of engineering has been most rapid and complete.

CHAPTER III.

CIRCULAR SAW BENCHES—*continued.*

In our International Exhibition of 1851 the exhibits of wood-working machinery were chiefly confined to Fay and Co., of Cincinnati, U.S.A., and Furness, of Liverpool, with one or two other machines of Continental origin ; but between this time and our next Exhibition—1862—a great number of machines, and improvements, and modifications on American designs more adapted to English necessities were introduced by Slater and Tall, Buchanan, Douglas, Barton, Bunten and Lamb. Jordan, Molesworth, Wimshurst, Messer, Varrall, Worssam, Forrest and Barr, McDowall, Horn, Furness, Kinder, Rosenberg, Robinson, Powis and James, and others. Under the head of circular saw benches, however, we do not find anything especially worthy of notice. In 1861 a patent was secured by Worssam, London, for improvements in machinery for cross-cutting timber. He claimed the arranging of two circular saws, one above the other, in the same vertical plane, the top saw being placed a little in the rear of the other, but both meeting in the same kerf. Additional guides were also used for assisting in supporting or steadying the saws before entering the wood. One or both saws could be used, according to the size of timber to be cut. They are, however, owing to the small size of our timber, little used in this country, and are generally known as American or Canadian rack benches, but were really the invention of Sayner and Greenwood, whose patent we noticed in our last chapter.

In our Exhibition of 1862 a considerable number of English, American, and Continental machines were shown. Messrs. Greenwood and Batley, Leeds, exhibited several very ingenious machines, including a curvilinear band sawing machine with a variable and self-acting radial motion, Kinder's shaping machine, &c. Messrs. Worssam and Co., London, exhibited a portable deal frame, band sawing machine, &c. Messrs. Powis, James, and Co., London, showed hollow-framed band sawing machine, planing machine, mortising machines, &c.; Messrs. Robinson and Son, of Rochdale, planing and squaring-up machine, tenoning machine, &c.; and a number of other machines were also exhibited by Messrs. McDowall and Sons, Glasgow; Kennan and Sons, Dublin; J. and T. Young, Ayr; Haigh, Oldham; Geeves, London; Weston and Horner, London, &c. A new tree-feller was shown by Mr. R. Thompson, of Woolwich. These machines, taken as a whole, were considered fair examples of design and workmanship, but were far behind those of the machine tool-makers in the massiveness of their framing and general compactness and simplicity of their details.

Amongst the Continental machines exhibited was a band saw and traversing mortising machine, by M. Périn, Paris, the former of which attracted a great deal of attention, chiefly from the very able manner in which it was worked. Messrs. Bernier and Arbey, and Messrs. Varrall, Elwell, and Poulot, of Paris, and M. Zimmermann, of Chemnitz, also showed a varied collection of wood-working machines, but nothing calling for special notice.

Immediately following the Exhibition, what must be considered one of the greatest improvements ever introduced in connection with wood-working machinery was brought out by Mr. Henry Wilson (then manager of the firm of Powis, James, and Co., London). This was what is known as the solid or 'box' framing—that is, instead of the frames of saw benches, moulding machines, &c., being bolted together in pieces, they are cast in one solid mass, thus securing greater rigidity, enabling saws, cutter blocks, &c., to be driven at a very high velocity without vibration. This was unattainable in machines hitherto made with light iron or wooden framings, although in former years it was argued that wooden framings were preferable to iron, the vibration of high-speeded cutters being absorbed by the elasticity of the wood. The fallacy of this reasoning has been amply disproved by the almost universal adoption of solid iron framings in this country, and more or less in America and on the Continent, America hitherto being the great advocate for the use of wood. Wooden framings might have the advantage of lightness and portability when used in unfrequented countries, and also be somewhat less in first cost, but where machines are fixed for permanent use there seems to be little doubt that solid iron frames are in every way preferable, being stiffer and steadier in their work, much more durable, and costing less for repairs. A number of other improvements were about this time introduced by Mr. Wilson, including a machine for sawing, adzing, and boring railway sleepers, for which he obtained a patent in the year 1864. The arrangement for sawing was briefly as follows:—'Endless belts carried the wood between uprights, the width of the rough sleeper to be prepared; six circular saws were erected, under which the belts carried the sleepers; the two outer saws cut the sleepers to the length required, while the other four saws were set in pairs and the proper position for making cuts to a certain depth in the sleeper, between which cuts, towards the ends of the sleepers, the wood is to be removed for the chairs to be seated. The belt then carries the sleepers under the adzes or sets of cutters revolving horizontally, whereby the wood between the two cuts last mentioned is removed, and the seats for the chairs are formed. The sleepers thus prepared are carried by endless belts to the boring machine, which is arranged to bore the four necessary holes in the sleepers either vertically or at an angle; after boring they were shot from the machine by the belts.'

Immediately following the Exhibition, Mr. W. B. Haigh, of Oldham, introduced various improvements into sawing machinery, including the mode of operating saw benches for cross-cutting purposes, in which, instead of making the bearings stationary which carry the spindle of the saw, they are made movable, so that the saw can be raised and lowered as desired. The driving band passes from any driving pulley over a carrier pulley, and around two other pulleys, and as one of them is central with the axis of a swing lever, the length between the two pulleys is the same at any position of the saw, and the tension of the band is the same in all positions. In large circular saw benches the swing lever is moved up and down by a worm, gearing into a worm wheel or quadrant fixed to the boss of the swing lever, so that when the worm is turned either by hand or steam power, one way, it will cause the worm wheel or quadrant to revolve and depress the swing lever and bring the saw below the table, in order to prevent accidents when the timber is being placed on the table, and when the worm is turned the other way it will bring up the saw and cut the timber as it rises, and, after the timber has been cut, the saw can be again lowered to be out of the way during the removal of the cut timber. In smaller saw benches the swing lever is moved up and down by a screw and nut or other convenient means.

A patent was also obtained by W. Jeffery, Glasgow, for an improved saw bench for cross-cutting purposes. In this machine the saw spindle was mounted in a slide, to which was given a self-acting reciprocating motion, by means of screw and bevel gear, arranged to reverse automatically by means of a weighted lever and stops. A slide plate could also be used for cross-cutting, the saw remaining in a fixed position. The wood was held against a fence on this plate, and pushed through the saw by hand, a weight attached to the sliding plate bringing it back to its original position after each cut.

Mr. Samuel Worssam, in 1863, patented an improved self-acting saw bench. The improvements related to the mechanical arrangements for moving the timber on the saw bench, consisting chiefly in the use of movable feed rollers and a pair of rotating rollers for returning the timber to its original position on the bench when a plank had been sawn therefrom.

Of the great variety of wood-working machines, the circular saw bench, in its many forms, is the one, perhaps, in most general use in all parts of the world, as before the wood can be submitted to any other process, such as mortising, moulding, &c., it must first be prepared on the saw bench. It is, therefore, of the highest importance that it should be well proportioned and adapted to the special class of work it has to perform; but this is far from always being carried out. We take it that true proportion denotes the just magnitude of the members of each part of a machine, and the relation of the several parts to the whole. If this was more generally borne in mind, we should not, I think, see so many 'abortions' turned out by so-called 'engineers,' which has taken from English machinery more or less the high character it once held, and has in several classes of industry proved a boon to our American rivals.

In wood-working, as well as other machinery, great care should be taken in designing; a certain weight of iron, correctly apportioned to bear the wear and tear and high speeds it is necessary to run at, is far better and more economical than twice the amount of metal used haphazard; but how rarely does this matter receive the attention it deserves. With some makers it seems that so long as a machine may be made to work after a fashion and sell at a certain price, their end is attained. This may be satisfactory to their pockets, but it certainly cannot be considered as conducive to true engineering progress. Of course there are some notable exceptions, and I think I cannot do better than refer to Sir Joseph Whitworth's machine tools as illustrating great excellence of design and proportion, and whose example in this respect it would be well for many to imitate.

As a wood-working tool, the saw bench has the disadvantage of requiring large power to drive, and wastes a considerable amount of wood. This drawback is, however, more than counterbalanced by its general handiness and adaptability for converting all kinds of wood, and its little liability to disarrangement.

Fig. 1 illustrates a double spindle or universal saw bench for ripping, cross-cutting, mitring, jointing, &c., by Thomas White and Sons, Limited. The main frame of the machine is cast in one piece, and fitted with a door to permit of the ready adjustment of the saws, and a solid partition is provided to prevent the sawdust coming in contact with the operating mechanism. The saw spindles are of high carbon steel, and are mounted on ball bearings, and in order to make the spindles perfectly rigid, the casing for the bearings forms part of a circular disc which revolves in a machined bed. The table and spindles are operated by machine-cut worm gearing, and three fences are provided to suit the various work. By substituting a cutter block for a saw, plain mouldings may also be cut.

The teeth of circular saws, to do the best and cleanest work, should travel about 9,000 feet per minute, and great care should be taken that the form of saw tooth is selected that is most adapted for the class of timber to be operated on, and that they should be accurately and properly sharpened, and have the right amount of 'set.' These points are oftentimes neglected, and the result is a considerable reduction in the quality and quantity of the work turned out. The 'packing' of the saws is also a matter of importance, as, if well packed, a saw of thinner gauge can be run, which is a saving in power and also in wood, which, when valuable woods are being sawn, is a matter of much more moment

FIG. 1.—UNIVERSAL SAW BENCH.

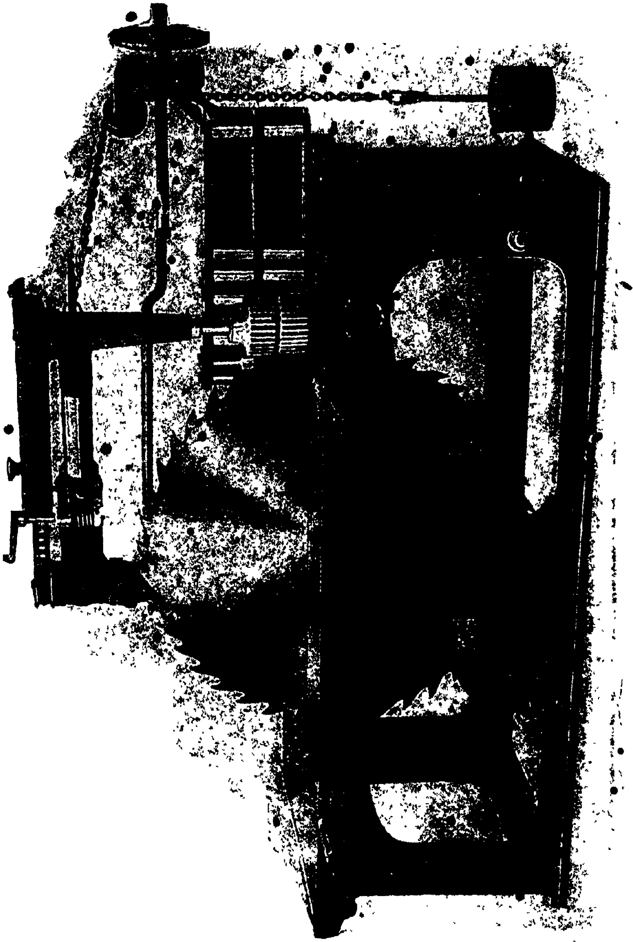

FIG 2.—CONTINUOUS ROLLER-FEED CIRCULAR SAW BENCH.

than would at first appear. I shall have something further to say on these points.

Fig. 3 illustrates an automatic continuous roller-feed circular saw bench specially designed for sawing deals, battens, &c., into boards, by John M'Dowall and Sons. The main frame is cast in one piece, and the saw spindle runs in three sets of bearings, one of which is arranged outside the driving pulleys to withstand the pull of the belt. The feed motion is driven from the saw spindle, and is arranged with four rates of feed varying from 25 feet to 100 feet per minute. The pivot for radial arm is mounted behind the saw, towards the delivery end of the bench, and is thus out of the way of the man when working the machine. This arm can be extended or contracted to suit saws of various diameters, or swung out of the way for jobbing purposes. The feed gear can be used for either deep or flat cutting.

When required for cutting window sills, architraves, weather boarding, &c., an additional angular fence and feed pressure roller is provided.

It is claimed that this bench is capable of sawing 25,000 of lineal feet of 9-inch deals into boards in a working day of ten hours.

It need hardly be said that the successful working of circular and other saws depends largely on the shape of the cutting tools. In the engineering profession committees have long been in existence for the purposes of research and standardisation, and we venture to suggest that something of the kind has long been wanted in the wood-converting industries, which are still largely governed by "the rule of thumb" as regards saws and cutting tools. For instance, the same circular saws are made to do duty for all kinds of woods irrespective of the shape, rake, gauge, set, spaces, and speeds of teeth. Of course any saw can be forced through wood, but the use of an unsuitable saw undoubtedly means loss of power, wood, output, and quality of work, and is detrimental to the saw itself. It would be impossible to have saws to exactly suit every kind of wood, but there is no reason why they should not be grouped according to their nature, and the most suitable teeth, &c., determined, if necessary, by a series of trials. The question as to the best speed for the saw and feed speed suitable for different woods could be also ascertained. The above remarks will apply equally well to frame, log, band, and other saws.

The question of mounting circular saws on the spindle is also a matter of importance, and care should be taken that, in addition to being absolutely round, they are an easy fit—to allow for expansion—but not a loose fit, as in this case the saw is thrown out of centre, and some of the teeth do not act on the wood. To secure absolute roundness in circular saws, and that the teeth are all shaped exactly alike, automatic saw-sharpening machines are now largely employed.

CHAPTER IV.

CIRCULAR SAW BENCHES—*continued.*

There are a considerable number of circular saw benches made with self-acting feed motions, to bring the timber up to the saw when too heavy or laborious to be pushed through by hand. These feeds vary according to the class of work to be performed. Mr. Samuel Worssam in 1873 received provisional protection for a simple feed especially adapted for deals and battens; before this date, however, the writer had applied the same plan to benches driven by hand. It consists of a grooved or serrated roller, or rollers, mounted in bearings underneath the table, whose periphery works partly in an opening in the table, and extends a slight distance above its surface, to ensure the wood to be cut resting thereon. Rotary motion is communicated to the roller by suitable gearing, capable of adjustment to enable the speed of the feed roller to be regulated as desired. Holding-down rollers, or means as heretofore used, are dispensed with, and the pressure of the saw when cutting is relied on solely to keep the wood in contact with the feed roller. Included in this specification is an improved method of 'packing' the saw. For this purpose loose blocks are employed on each side of the saw, each block being fitted with adjustable packing pieces. The loose blocks are fitted in guides, fixed to the under side of the table and to the 'filling in piece,' and two screws are fitted to each block, to work in nuts carried by the table and the filling-in piece, so that the ends of the screws extend to the outer edges of the table. Thus by turning the screws the loose blocks, with the packing pieces therein, can be adjusted for different thicknesses of saws.

No very striking novelty in connection with circular saw benches was shown in the recent International Exhibition in Paris. Messrs. Bollinder, of Stockholm, exhibited a saw bench for edging purposes. It was fitted with a horizontal plain roller-feed. Part of the top of the bench and one saw were adjustable by means of a hand lever to the widths of the wood. A neat pendulum or vibrating cross-cut saw, especially designed for sawing barrel staves, was shown by F. Arbey, Paris. The stave to be sawn is bent under a powerful spring, placed on a swivelling frame, which can be set to any angle. The pendulum with saw is brought over by hand, and one side of the stave is sawn; the swivelling frame is then set over the width of the stave, and the saw performs the same operation on the other side.

A small machine for sawing out wooden cogs was shown in the Swiss section. The wood is fixed in a vice fitted on a circular revolving table, and is operated on by two circular fine-toothed saws, running vertically and horizontally; when the tooth is cut on one side, the circular table is made to revolve, and the other side of the wood is served in the same manner.

Important though the subject is, our space will not permit us to notice all the varied forms and modifications of circular saw benches and their adaptation to different classes of work; we shall, however, briefly notice some few of the most important. For cross-cutting heavy logs, where any considerable quantity are done, the best plan is to arrange at the end of the saw mill where timber enters, below the floor, a large circular saw, which can be raised and depressed by suitable gearing above and below the floor line, and cut through the log as it lies on the ground; this effects a considerable economy in labour, especially when the timber has to be converted by other machines and the full length of the log is not required. For light cross-cutting purposes, a pendulum bench is a very useful form; in this case the saw is fixed to a frame or pendulum, which swings on a countershaft below the floor line. The saw is made to oscillate by self-acting gear, or can be brought to the wood by means of a treadle. The number and length of the strokes can be varied to suit the different widths of boards. A somewhat novel feature has latterly been introduced in this class of cross-cut bench—we believe by Messrs. A. Ransome and Co., London. It consists of a self-acting stop, which can be set to gauge any required length of board. This stop is brought into position when the saw is retiring after making its cut, and moves out of the way as it advances, so as to allow the boards sawn at the last stroke to fall out of the way immediately after they are cut. For cross-cutting heavy scantlings, deals, &c., various modifications of ordinary saw benches are introduced, the saw, by suitable gearing, being made to advance through the wood and retire to its first position ready for the next cut; these modifications vary according to the size and class of work to be done. As a rule, it must be considered preferable for the saw to be made to pass through the wood, instead of the wood being pushed through the saw. For sawing railway sleepers, benches are generally arranged with an endless chain, working on rollers of corresponding pitch. This chain carries loose 'dogs,' which grip the end of the timber. As each sleeper is sawn, the 'dog' is removed, and placed at the end of another log; a continuous feed is thus obtained.

In small establishments, or when constant changes are made in the work, a ripping and cross-cutting saw can be combined in the same bench by mounting two saw spindles in a revolving frame placed beneath the bench, which can be moved round by a hand wheel and worm gearing, thus bringing into operation above the level of the bench either the cross-cutting or ripping saw, as required. Saws of small diameter can be driven by friction discs. When much light wood has to be cut to a certain length, as in box-making, a convenient plan is to mount the saw in a slide which can traverse backwards and forwards through the wood by a hand lever, an uniform tension of the belt being secured by passing it over pulleys fitted in a vibrating or pendulum frame. For edging purposes three or more circular saws can be mounted on the same spindle, and a horizontal roller-feed attached. Both the feed and saws should be made adjustable for different thicknesses or widths of wood by worm or rack and pinion gear. The feed rolls can be driven direct from the saw spindle.

For grooving and rebating purposes the saw spindle runs in bearings fixed on a slide working in a bracket bolted to the under side of the bench; thick saws of about 12 in. diameter, varying according to the width of groove to be cut, are used in place of the ordinary ripping saw. By means of a hand wheel and screw, the slide can be raised or lowered for the saw to project above the surface of the bench the exact depth of the groove to be cut, and the wood is passed over it in the usual manner. Benches are also fixed on wheels for forest use, or where they have to be constantly moved from place to place, and are often otherwise varied in their constructive details to suit special conditions or circumstances.

Fig. 3 illustrates a combined horizontal and vertical feed saw bench, by Thomas Robinson and Son, Limited. The machine is used for sawing small logs, sleepers, &c., and in conjunction with breaking-down frames for resawing the large flitches into which the log is first cut.

The frame is a massive cored casting, and the construction throughout is particularly strong.

The saw spindle runs in three enclosed ring-oiling gun-metal bearings, which are bolted to planed seatings cast in the frame. The driving pulleys are carried between two of the bearings.

The fence is adjustable in all directions, and can be moved up to 14 inches from the saw. It is also sometimes made to cant.

The combined feed of this machine is worthy of note. In log cutting the horizontal rollers are brought into play for feeding, being power-driven. They stand slightly above the bench, and carry the log forward. The weight of the timber and the downward pressure caused by the action of the revolving saw are sufficient to ensure a regular and efficient feed. The vertical feed rollers can

be used in conjunction with the horizontal feed to hold the flitches up to the fence.

The horizontal feed rollers have reversing motion for the return of the log, and the handle which reverses the horizontal feed motion at the same time throws the vertical feed out of gear. There is thus no possibility of a sawn board being returned against the saw by the vertical feed rollers.

When resawing deals and flitches into boards the vertical feed is brought into action. It consists of two toothed rollers mounted on a radial arm carried from the back of the bench. The rollers can be adjusted vertically for different heights of timber, and the radial arm automatically adjusts itself to different thicknesses; it is chain-driven. Mr. G. L. Molesworth, C.E., introduced in the year 1856 a self-acting revolving wedge, in the shape of a wheel, thick at its centre and sloping down to an edge at its circumference; it revolved on centres at the end of a lever, which was free to traverse along the feather of a rocking shaft. The rocking shaft had a lever, which caused the wedge to be held with an even pressure within the cut. The whole was arranged close behind the saw, and the wedge revolved by the friction of the wood as it advanced, and exerted an uniform pressure in relieving the saw, and could also adapt itself to irregular as well as straight sawing.

Fig. 4 illustrates a rack-feed circular saw bench for breaking down logs into scantlings, &c., by A. Ransome and Co., Limited. The timber is carried to the saw upon a double bed steel travelling table arranged with a rack-feed which can be varied from 12 feet to 40 feet per minute, and has a return motion of 150 feet per minute. All the gearing connected with the feed and return motions of the table are attached to the main bed of the machine,

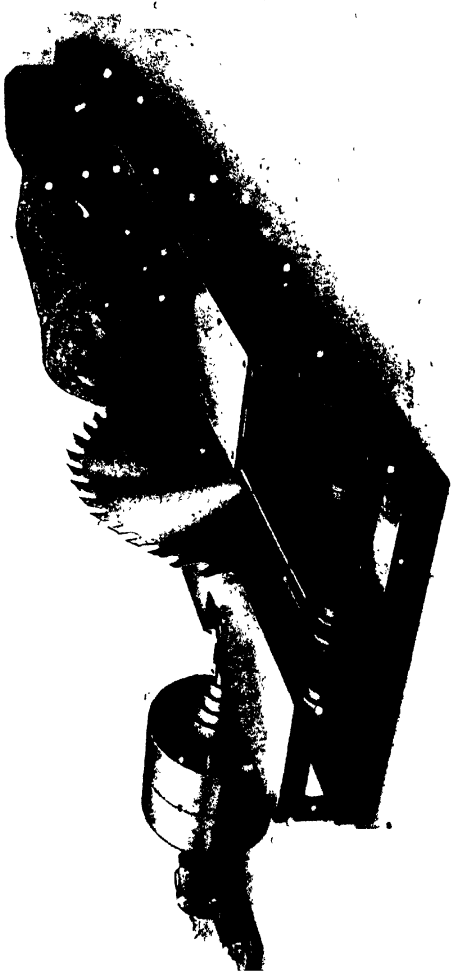

FIG. 4.—RACK BENCHES WITH STEEL TRAVELLING TABLES.

thus making it self-contained. Many of these machines are fitted with a variable friction feed (Miles' Patent) which enables the speed of the feed to be varied whilst the machine is in motion, an advantage when dealing with rough or crooked timber. With this feed the backward and forward motions are both driven from the saw spindle which is fitted with self-lubricating, self-oiling bearings. By this arrangement the necessity of having an independent drive for the back motion is avoided, and when the machine is electrically driven the motor can be coupled directly to the saw spindle.

We have noticed recently an improvement in imparting motion to rack-bench tables. It consists in working the rack and pinion by which motion is imparted in a horizontal plane, instead of a vertical, as hitherto, the side of the rack being bolted to the under side of the table instead of the back. The objection to the vertical method is that sometimes work has been damaged by the rack riding on the driving pinion, and thus raising the table.

Circular saws up to about 7 feet diameter, but not above, can be worked with advantage, notwithstanding the large power required to drive them. Timber requiring saws of greater diameter should be converted by reciprocating or straight saws. In America circular saws are used of much thicker gauge than in this country, and without packing pieces. This practice, however, must be condemned, both on the score of wastefulness of power and wood; neither is the work done so clean or true. Less skilled labour may perhaps be used, but even this is a doubtful economy. Crown and cylinder saws are used somewhat in the United States, but rarely here. A dished circular saw for cutting out curved forms was invented by a Mr. Trotter in 1806, but the band and fret saw has now entirely taken its place.

It was the practice of some American engineers to make the top of their saw benches of narrow strips of different woods glued up together, but this has now almost entirely been abandoned in favour of iron. Many of their benches are fitted with spindles arranged with an expanding end, to suit saws with holes of different sizes; this is worked by means of a screw at the one end of the spindle, and obviates the necessity of bushing the saw spindles.

In purchasing or making a saw bench, where low first cost is not an object, and where a really durable and efficient machine is desired, care should be taken to have the saw spindle made of Bessemer or other steel, of not too hard a texture; or, if iron is used, it should be of the best, and free from seams, or the bearings will rapidly be worn away, and sometimes 'fired' by the friction, besides requiring constant lubrication. The bearings should be of best gun metal, or, better still, of phosphor-bronze to which metal we hope to refer again, as its merit for bearings is great, its increased cost only, we believe, preventing its general adoption. We have seen bearings composed of an alloy of 100 parts of tin, 10 parts of antimony, and 2 parts of copper used, and they are reported to wear longer than gun metal; but of this we cannot speak personally. We should imagine for heavy machines this alloy would be much too soft. With spindles carrying saws above 36 inches in diameter, there should be three sets of bearings, which should be placed as far apart as the width of the bench will permit; one set on the outside of the driving pulleys. The driving pulleys on the saw spindle should not be of too small diameter, and should be sufficiently wide to carry belts; a safe rule is, say, one-quarter of the diameter of the saw used. Efficient lubrication of saw spindle should be secured, and is of great importance, as should heat from the spindle be communicated to the saw, it destroys the stiffness of the plate, and gives a tendency to 'buckling.' Care also should be taken that it is worked at its right speed, as it is found that, if run at too great a rate, it becomes wavy and pliant, and runs untrue. We have already spoken of the best form of framing, and, in concluding our remarks on these points, we should recommend buyers not to be tempted by a very low price, as they will find it impossible to purchase a good and useful machine without paying a fair price for the design, workmanship, and materials embodied therein. We may mention that the smallest circular saws in use in this country are, we believe, those employed in the manufacture of pens, and they range about half an inch in diameter.

For saw benches cutting above 12 inches deep, self-acting feed gear is to be recommended, as the labour of pushing the timber through the saw is excessive. For plain jobbing benches, at any rate the larger sizes, turned revolving rollers should be placed at the front end of the bench, as this lessens somewhat the labour required in feeding by hand. For very light or ornamental work a small saw-bench can conveniently be driven by the foot. The top of the table outside the saw should be arranged to angle for cutting mitres, and the whole table-top made to cant endways for light rabbeting, grooving, &c. When 'drunken' saws—that is, those fixed obliquely on their spindles—are used for grooving in preference to saws of a gauge the same thickness as the groove required, if the collars employed to keep them in position are made to a considerable bevel, they can be so arranged by turning them round, that, with one set of collars, the saw can be set to almost any angle to cut any width groove desired, or it can be fixed at right angles to the spindle for ordinary sawing. This plan does away with several sets of collars. The peripheries of circular saws should be speeded to travel about 9,000 feet per minute.

CHAPTER V.

TIMBER AND DEAL FRAMES, ETC.

UNDER the above heading we purpose noticing the varied forms of machines generally known as reciprocating or mill saws. The straight or mill saw was known and in use some hundreds of years probably before the circular saw. The date of its introduction; and when it was first driven by other means than hand power, is uncertain; several writers, however, mention the fourteenth century as probably the earliest period. Montfaucon ('L'Antiquité Expliquée,' vol. iii., pl. 189) gives a representation of two ancient saws taken from Gruter, one the blade of a saw without any frame, and the other apparently a cross-cut saw. Some interesting accounts of an early saw frame or mill, as it is called, are given in Hardwicke's 'Miscellaneous State Papers,' from 1501 to 1726, p. 71. In the year 1555, the ambassador from Mary, Queen of England, to the Court of Rome, having noticed a saw mill in the neighbourhood of Lyons, describes it as follows:—'The saw mill is driven with an upright wheel; and the water that maketh it go is gathered whole into a narrow trough, which delivereth the same water to the wheel. This wheel hath a piece of timber put to the axle-tree end, like the handle of a broch, and fastened to the end of a saw, which being turned by the force of the water, hoisteth up and down the saw, that it continually eateth in, and the handle of the same is kept in a rigall of wood from swerving. Also the timber lieth as it were upon a ladder, which is brought by little and little to the saw with another vice.' Before the introduction of saw frames driven by water or wind, timber was generally converted by the aid of the wedge and pit saw; the latter had a reciprocating motion given to it by two or more men. In isolated districts, or where little timber is required, these saw-pits are in considerable use even at the present time, and men can be found willing to convert some classes of timber at a cost not greatly in excess of that sawn by machinery; the process is, however, much slower, and as a rule not so well done. The earliest saw frames in use in this country were constructed almost entirely of wood, and are described by an old writer as follows:—'The common saw-mill, which is generally employed in cutting timber into planks, consists of a square wooden frame, in which a number of saws are stretched; this frame rises and falls in another wooden frame, secured to the foundation of the mill in the same manner as a window sash rises and falls. The timber to be cut is placed upon a horizontal bed or carriage, sliding upon the floor of the mill, which being sufficiently narrow to pass through the inside of the vertical or moving saw-frame, will carry the tree through, and subject it to the action of the saw. The carriage is provided with a rack, which is engaged by the teeth of a pinion, and thus gives the means of advancing the carriage. The pinion is turned by means of a large ratchet-wheel, with a click moved by levers connected with the saw frame; when the saw frame rises the click slips over a certain number of teeth of the ratchet wheel, and when it descends to make the cut, the click turns the ratchet wheel round, and advances the wood forward just as much as the saw cuts during its descent. The trees are generally dragged up an inclined plane, through a door at one end of the mill, and being placed upon the carriage, they pass through, and are divided by the saw into two or more pieces, which are carried forward, and passed out at a door on the opposite side of the mill.'

Bentham, amongst other machines, supplied a number of saw frames to the Government establishments at the close of the last and the commencement of the present century. We do not find, however, record of any special invention made by him in relation to this particular class of machine. In 1805 and 1807 Brunel took out patents for improvements in sawing machinery, included in which was a method for fixing and tightening mill saws, which was introduced by him at the Royal Arsenal, Woolwich, and elsewhere. It may be described as follows:—Each saw has pieces of metal formed like hooks riveted on either end. The hook at the lower end of the saw falls into a proper recess made in the lower cross-bar of the frame, and the upper hook is engaged with the hook of a shackle or link which hangs upon the upper cross-bar, and has wedges through it, by means of which it can be drawn tight to strain the saw. As the tension of the saws is in a measure uncertain when the wedges of the shackles are merely driven by a hammer, Brunel employed a very ingenious steelyard, which exhibited the degree of tension given to the saw. A strong spindle extended across the fixed uprights in which the saw frame slides, and above the top of these uprights, from one side of this spindle, a lever proceeds, which has a weight fixed at the end, and from the opposite side of the spindle two short levers are fixed. They were connected by links to a cross-bar, situated just over the upper cross-bar of the saw frame when it is at its greatest point of elevation. This cross-bar of the steelyard has a shackle upon it, which can be united by a key with any of the shackles upon the cross-bar of the saw frame, which shackles are, as before mentioned, united by the hooks with the upper end of their respective saws, and by this means the lever and its weight become a steelyard, to draw up any one of the saws with a determinate force. In using this apparatus, the crank is turned round to elevate the frame to the highest point. Two wedges are then put in between the saw frame and the uprights, and this holds the saw frame fast whilst the steelyard is applied. The sharpened saws are now put into the saw frame, by hooking them upon the lower cross-bar, and uniting the hooks to the shackles on the upper cross-bar. The link upon the cross-bar of the steelyard is united with the shackle of one of the saws, and by allowing the steelyard to descend it stretches the saw, the wedge being thrust in by hand as far as it will go, thus retaining the saw at the tension to which the steelyard has stretched it. This same operation is performed on all the saws, which are thus strained equally. Brunel also erected several reciprocating saws for the Government, including one working a specially thin-gauge saw with fine teeth, for cutting sheaves from lignum vitæ. The plan of holding and feeding the timber to be operated on is ingenious.

The tree of lignum vitæ is placed horizontally in a large vice, which is opened and shut by two screws, both moved at the same time by cog wheels, connecting them so as to move the jaws of the vice parallel. The machine being used for cutting the ends of the trees into proper thicknesses for the sheaves, the vice which held the tree was provided with a screw, which advanced and gave the proper distance every time a sheave was cut off. The vice was fitted on parallel slides, so that the pieces cut off should have parallel sides. This machine was used for cutting up the largest-sized trees, the smaller being converted by a circular saw fixed in a horizontal swinging frame, similar to the action of a gate or door. The timber was also made to revolve, thus presenting every part of its circumference to the action of the saw; the saw was therefore enabled to cut through a tree nearly its own diameter. The whole arrangement was decidedly clever, but our space precludes more than a passing notice. We must not, however, omit to add that Brunel was most ably seconded by the late Henry Maudslay, who carried out the inventor's ideas with the greatest skill and accuracy, and introduced many improvements of his own.

A patent was granted to Charles Hammond, London, 1811, for improvements in machinery for sawing and planing wood, described in which are feed rollers for bringing the timber up to frame and circular saws, &c. This same plan of feeding timber has been adapted to planing, moulding, and other machines, and has formed the subject of several patents, including that great American monopoly, the Woodworth planer.

We have before us the drawing of a deal frame for cutting two deals at once, constructed some fifty years since by a Mr. Haigh, of Ratcliffe, for the Dutch Government. The framework, saw frame, &c., are made of iron, instead of wood, as generally hitherto used. The saw frame has square, vertical, adjustable guides, rack feed-motion, with ratchet wheel and paul, adjustable friction rollers, fly wheel, fast and loose pulleys, &c. In fact, it differs very little in essential particulars from many deal frames now made, and, considering the date at which it was built, must be considered a first-rate specimen of engineering skill. About this time also a machine or apparatus for cutting piles under water by means of a reciprocating saw was introduced; who its inventor was is uncertain, but it was probably of Continental origin. The machine employed for this purpose is required to give the saw three motions—the first, by which it descends below the level of the water, at the same time preserving the blade of the saw in a horizontal position; the second, a horizontal motion in the direction of the length of the saw; and the third, a horizontal movement in the direction of the breadth of the saw, which enables it to follow its work as it advances into the pile. This was effected in the machine under notice by two platforms, one of which was made movable by rollers on a framework attached to the top of the piles, where the workmen stand in working the saw; the second platform was placed below this, and attached to it by four rods, with racks and pinions, by means of which it could be raised or depressed, according to the depth below the level of the water the pile was required to be cut off. The saw was fixed to a carriage, which was movable on the lower platform, on rollers in the direction of the breadth of the saw. A rack was attached to the carriage, which engaged a pinion working in the lower platform; by this means, the carriage and saw were pressed forward against the pile.

Saws or blades for cutting stone, marble, &c., driven by steam, were also now in use. The saws were stretched in a strong frame, and received a horizontal reciprocating motion from a steam engine. A very complete marble mill was made by a Mr. Colliss, and erected in the neighbourhood of Kilkenny about the year 1830; the machine was arranged to work twenty saws and five polishers. The saws were of soft iron, and lasted about a week, and were worked with sand and water. The marble taken from the mill was first polished with stone called cove stone, which is a brown sandstone; it was afterwards polished by a hone stone, which was a piece of smooth nodule of the argillaceous iron ore found in the hills between Kilkenny and Freshford; it received its last polish in the mills with rags and putty.

In 1835 Messrs. Gibbs and Gatley took out a patent for 'certain improvements in machinery for cutting wood and other materials.' The improvements chiefly relate to combinations of machinery specially adapted for cask-making, but included in the specification under claim No. 5 is, 'in constructing an ordinary vertical saw frame or machine in such manner that one set of saws and their frame shall at all times balance another set of saws and their frame.' This improved counter-balanced saw-frame was fully illustrated and described, and from the illustration it is seen that the two cranks are on the same plane in opposite directions, and that, therefore, the resistance of the cut and the weight of the saws will be balanced at every point of a revolution. This arrangement has been the subject of at least one patent since the above date, but we are at a loss to see wherein the originality of the later patent lies, except, perhaps, in the matter of small details. This affords one of the many instances of the haphazard manner in which patents are granted, and also, the need that exists for reformation in this as well as other points in our present system of patent administration.

Following 1835 we do not find for some years any inventions or improvements of importance relating to reciprocating saws. In 1848 T. H. Barber, of London, took out a patent, in which a great many contrivances are described, including some improvements in saw frames; but the specification relates chiefly to bevel-sawing, and means for facilitating the same. In 1850 Mr. Amos Jackson, an American, brought out a machine which he proposed to drive by the weight of the log to be sawn. Although unpractical, the originality of the idea merits a short description. The rails on which the timber carriage travelled were fixed on bearings attached to a frame, the opposite ends of which were fitted with large segments of a toothed wheel, working into a series of toothed wheels and pinions. When the log was pushed forward to the saw, its weight was to act through the segments on a shaft having several intermediate gearings, which would increase the speed sufficiently to drive the crank shaft. The saws proposed to be used were to be made thick at the points of the teeth, tapered to a thinner gauge at the back of the saw, and to be run without setting. In 1852 Mr. John McDowall, of Johnstone, brought out and patented 'a high-speed tension sawing-machine.' It consisted of a single mill-saw, driven at a high speed, with an arrangement for giving increased tension to the saw, without using the ordinary heavy saw frame and buckles; also an adjustment for regulating the 'overhang' of the saw, according to the rate of feed given to the timber.

CHAPTER VI.

TIMBER AND DEAL FRAMES, ETC.—*continued.*

IN the year 1854 Mr. James Hamilton, of New York patented an arrangement of vertical saws especially adapted for cutting ships' timbers. A machine, made under this patent, was erected at the shipbuilding yard of Messrs. Wigram and Son, Blackwall. The machine ran two saws, which cut both sides at once of any timber ordinarily used in shipbuilding. Each saw was hung in such a manner as to be free to turn on its centres, and present its cutting edge in any required direction; they were also arranged to move laterally in the saw frame. This movement was obtained by stretching each saw in a separate frame, which frame slided sideways within the principal frame. The sawyer controlled the position of both the saws by holding a lever or guide in either hand, and thus manipulated, each saw was made to follow the line on the timber to any desired curve or taper. The bevel of the timber was obtained by causing it to revolve somewhat as it was fed up to the saw, and the exact bevel necessary at every point was thus secured, and the timber left the saw sufficiently true to require little or no trimming. An adjustable crank or disc for varying the length of stroke of saw frames, and some other improvements, were patented by S. B. and A. Sparkes in the year 1857.

In 1859 the late Mr. Samuel Worssam, of London, brought out and patented several important improvements connected with timber and deal frames, foremost amongst which was an improved feed for saw frames. It consisted of an eccentric paul or pauls working in a grooved wheel. The paul was connected to a lever, which was keyed or otherwise fixed on the shaft or roller which drives forward the wood to the saw. The rate of feed could be varied from 1 foot to 4 feet per minute, according to the nature of the work, the number of saws carried, &c. This feed has the advantage of being nearly silent in its operation, and is now in very general use. Included in this specification is an improved 'sling' connecting-rod for driving saw frames.

In the Exhibition of 1862 Messrs. Worssam exhibited a very complete portable deal frame, designed chiefly for builders' use, adapted to work about ten saws. The whole of the working parts were fixed on a cast-iron base-plate; the connecting rod was worked from a single crank, and was looped, to clear the rack which passed through it. The feed was the patent arrangement to which we have just referred. A vacuum cylinder to balance the weight of the swing frame was applied at the top of the fixed frame. This cylinder was fitted with the usual piston and piston rod; the latter was connected with the swing frame. As the swing frame descended, and the piston with it, a vacuum was formed in the upper end of the cylinder, and the resistance of the air in the lower end of the cylinder balanced the weight of the moving frame; a valve at the upper end of the cylinder allowed any air that might leak above the piston to escape. This idea was, however, not novel, as a similar arrangement was introduced, we believe, by Mr. James Neil, of Glasgow, about the year 1851. We may here describe a very novel method of stretching saws by means of compressed air, introduced and patented in America by Messrs. Rapp and Wright about this time; we have, however, never seen it in use in this country, and doubt its utility, but from its novelty, if nothing else, we think it deserving of notice. The saw was stretched by the aid of two polished rods which pass through stuffing boxes into cylinders, where they were attached to pistons, which received the pressure of the compressed air. The contiguous extremities of these cylinders were put in communication by means of a pipe, so that whatever pressure was generated beneath the top piston was equally felt above the bottom piston. The air was provided by means of a small pump, which made good losses by leakage. As the saw moved up or down, the air changed its position, rushing through the pipe from one cylinder to another. By means of the compressed air, the inventors claimed that they could stretch saws to a sufficient tension without the usual saw frame, thus enabling saws of a thinner gauge to be used and a higher speed to be run, but we are afraid anything gained in this particular would be more than counterbalanced by the manifest disadvantages of the plan. A number of saws stretched in this manner were, however, we believe, made, and used in Buffalo and other parts of America.

In our Exhibition of 1862 Messrs. Powis, James, and Co., London, exhibited a machine with a combination to cut both timber and deals, which was then somewhat of a novelty. The timber was fed by means of fluted rollers, and was kept steady by universal jointed pressure rollers at the sides and top, acted on by springs to adapt themselves to inequalities of surface. The cross-heads of the swing frame were of steel, and, counterbalanced by fly wheels, the frame was arranged to drive from above or below at 190 revolutions per minute, carrying saws adapted to cut timber 26 inches deep. Messrs. J. and T. Young, of Ayr, also exhibited a frame adapted for cutting deals. With the exception of its being driven from the top of the machine by an extra long connecting rod, it did not possess any special feature.

In the year 1863 Mr. W. B. Haigh, of Oldham, patented various improvements in connection with vertical saw frames, and direct-acting engines for driving same. The swing frames were arranged on the equilibrium or balancing principle, and were joined by connecting rods to cranks set at half-centres on the shaft of the steam engine, in order that the swing frames may move in opposite directions and balance each other, and also enable the piston of the steam engine to have equal work at all parts of its stroke. The saw frame is connected at the front to the piston rod, and at the back to the connecting rod, so that the pressure of the cut is divided between the piston rod and the said connecting rod, and thereby gives equilibrium to the strain upon the working parts; but, when desired, the piston rods can be at the back, and the connecting rods at the front. The shaft of the steam engine is central with the half-stroke of the piston, and the connecting rods are brought down from the piston rod to the cranks which arrangement saves the length of the connecting rod and shortens the framework to a corresponding extent. The feed is given to the timber in the usual manner by two separate eccentrics working on the crank shaft, and connected by rods to pauls working in two grooved wheels fixed to the shafts of the fluted rollers on which the timber rests, and the fences against which the side of the timber is in contact are adjusted by set screws and fixed to the stationary frame. The rollers for keeping the timber against the fences are connected to two vertical shafts, working in bearings at each side of the frame, and to each shaft is fixed a lever, attached to a spring by a rod, having a screw sufficiently long to shift the roller for taking in various thicknesses of timber, there being on the screw and against the lever a nut in a hand wheel, which is turned to shift the lever and the roller and give the necessary friction against the fence. The holding-down rollers are connected to large nuts working on screws in connection with springs in the usual manner, for the purpose of adjusting the rollers to the various sizes of timber to be sawn.

In the steam engines for working the saw frames the slide box and valve are placed at right angles to the length of the cylinder, and the steam passages are arranged accordingly, in order to work the slide direct from the eccentric by a straight rod.

Following the Exhibition of 1862, Mr. Charles Frazer, of Norwich, introduced and patented several improvements in deal frames, one of which was the introduction of feed rollers on the fence side of the deal, working in conjunction with a wide feed-roller acting on its other side, thus securing a greatly increased feeding power. He also claimed the use of counterbalanced saw frames; but this plan, we think, can hardly be considered novel, as it is described in Gibbs and Gatley's patent, dated 1835. Frames built on this plan, however, can be driven at a greatly increased speed. Whether this is an advantage or not has been the subject of so much discussion amongst engineers, that we shall not enter on the question here. Each swing frame is fitted with a separate feed motion, so that on one side of the frame a deal can be fed through the saws at the rate of 5 feet or 6 feet per minute, whilst on the other side of the frame a piece of hard timber could be made to travel, say, 1 foot per minute.

In 1867 Mr. Samuel Worssam patented an improved method of packing timber on saw frames and trying-up machines, by which the supporting table is provided at short intervals with several transverse rocking supports, which, when wedged up from below, will fit against the under side of the timber and will take the weight of the timber at several points, whatever may be the unevenness of the under side.

Messrs. Robinson and Smith, of Rochdale, have recently patented several improvements connected with timber and deal frames, including an arrangement for rising and falling the rollers, carrying the tree whilst being sawn, thus rendering them adjustable to any inequalities of surface in the timber, and making breakage less liable when sawing crooked and uneven logs. An improved method of cutting scantlings is also introduced, by which means this class of work can be cut at a greatly increased speed. The connecting rod is arranged to take hold of the saw frame at the centre of each side, instead of the bottom, as hitherto. By this plan increased strength of frame, ease in working, and less depth of foundation are the advantages claimed.

In the recent (1878) International Exhibition, held at Paris, several timber and deal frames were shown, but none containing any especially novel feature. Messrs. Bollinder, of Stockholm, exhibited a strong roller-feed timber frame. The bottom feed-rollers were constructed with sharp toothlike projections; the top rollers were plain. The teeth of the saws were spaced extremely coarse, adapted, we presume, for sawing sappy timber. In the Austrian section the Ateliers de Construction of Budapest showed a powerful timber frame fitted with roller feed, which was adjustable by a simple rack and pinion arrangement. The feed rollers were all geared, and the swing frame was driven by double connecting rods placed within the main framing. Several frames were shown in the French section, notably by F. Arbey, of Paris. In some of them the swing frame was fitted on the face of the main framing, instead of in the centre, as is usual in this country, and motion was given by double wooden connecting rods and fly wheels placed on either side of the uprights. Inferior and flimsy castings marred in a great measure, however, their general appearance.

Various other improvements have recently been introduced by Messrs. Meadows, of Heaton Norris; Kirtland and Anderson, of Dundee; Worssam, Johnson, and Hewetson, Haigh, and others, but our space prevents more than a passing notice.

Fig. 5 illustrates a self-contained, roller-feed, vertical saw frame driven from above by belts, by John M'Dowall and Sons. This machine has been especially designed for

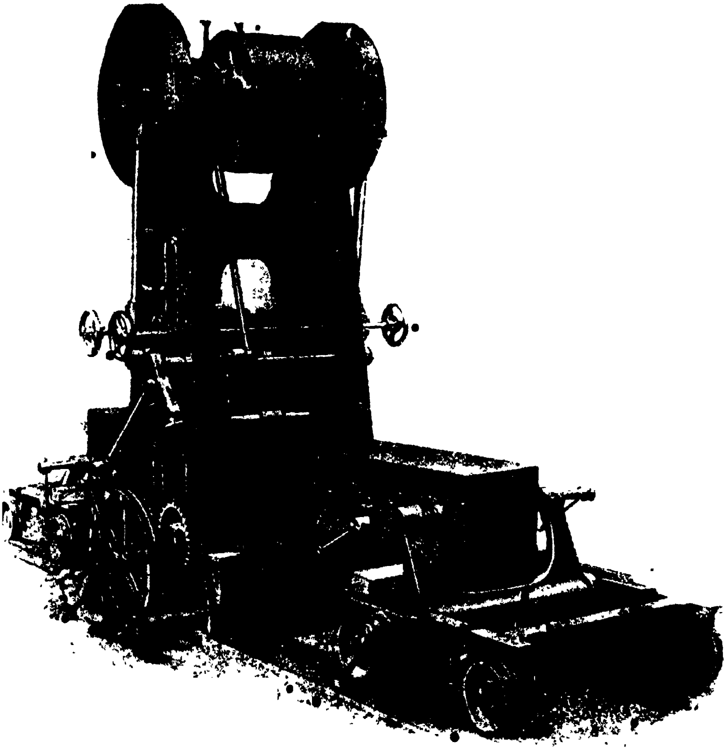

FIG. 5.—IMPROVED SELF-CONTAINED VERTICAL SAW FRAME.

[*To face page* 50.

sites where it is difficult to get foundations sufficiently deep to drive from below. The crankshaft driving the swing frame is mounted overhead on the top of the side frames, a reciprocating motion being given to the swing frame by means of two outside connecting rods coupled to it, near its centre. The rate of feed can be adjusted to suit the size and nature of the timber by means of a silent feed wheel of V section, if desired, an apparatus can be fitted to this machine, by which two deals or flitches of timber can be cut at the same time. The machine shown is fitted with a roller feed, but for hard and crooked timber a rack-feed—which avoids slip—is often preferred.

Although log band and re-saws have of late been largely introduced, and have for certain classes of work somewhat superseded vertical log and deal frames, these latter are still largely used, and although they do not turn out so much work, they require less skilful management.

Vertical log frames have of recent years been considerably improved in their working details, and a machine built on the following lines can be recommended for general purposes where an adequate foundation can be obtained—a central driven roller-feed frame with a long stroke. In these machines the driving pulleys—which should be of large diameter—are placed in the centre of the machine between the bearings, and the swing frame is operated by outside connecting rods attached to balanced fly-wheels placed on each side of the frame. The swing frame should combine strength with lightness, and have all the reciprocating parts carefully balanced.

There are a considerable number of modifications of reciprocating saw frames designed and especially adapted for particular classes of work. These machines differ considerably in their feeding and other details, but we shall be unable to give them more than a passing notice. For general log-sawing, where the timber is tolerably straight, the ordinary vertical saw-frame, fitted with a roller feed-motion, is the best type to be employed. This roller feed is continuous, and allows the logs to follow each other through the saws without stoppage. Care must be taken that the timber has a good bearing on the feed rollers, the straightest side of the log being placed on them. Some makers, in addition, so arrange that the rollers can be raised or lowered by the sawyers in charge, and adapt themselves to any inequalities in the log. For very irregular and crooked timber, frames are made specially strong in their details, and what is known as the 'rack feed' is usually employed, a rack actuated by a pinion being the method of bringing the wood up to the saws. The rack is bolted to the under side of the travelling carriage on which the timber is placed. This carriage is usually made of cast iron, truly planed, and running over turned rollers, which revolve in cast-iron brackets, fixed to the floor of the mill at either end of the frame. The log is supported in front and behind the saws by adjustable friction rollers, arranged to rise and fall and adapt themselves to any irregularities of the timber. By these means a firm bearing is obtained as the saws enter the wood, and thus the vibration and thrust of the saw frame is overcome. The ends of the log are held by cast-iron carriages, which have a lateral motion. They are also fitted with adjustable wrought-iron jaws, which are opened or closed at pleasure by means of screws. The log is kept firmly on the travelling table, usually by weighted pressure-levers, which can be easily adjusted by the sawyer in charge. Saw frames for forest use are made so as to be semi-portable or portable, the latter being mounted on wheels; they do not as a rule, however, differ essentially from those just described, except that the main standards of the machine should be bolted to a massive bed-plate, which dispenses in a great measure with other foundations. In regions where the trees to be sawn are sometimes covered with ice, and likely to slip, it is necessary to have greater feeding power, to carry them safely through the saws. This can be secured by employing four serrated feed-rollers, instead of two, as is usually done. These rollers all gripping the wood at one time, immense extra feeding power is thus gained; the top pair of rollers are made to adjust themselves to the varying thickness of the timber. Frames can be arranged to cut two, four, or more logs at a time, if necessary.

For cutting valuable woods into thin boards for use as coach panels, pianoforte tops, &c., a single-bladed frame, driven either vertically or horizontally, is usually employed. In these frames, which require little power, very thin saws are used, to prevent unnecessary waste of wood. They are usually fitted with a variable, self-acting rack-feed, to suit hard or soft woods, and the saws are arranged to cut both ways of the traverse. The advantage of these frames for this class of work is, that as they only saw one board off at a time, an opportunity is given to examine the soundness of the log as cut, which, if not found suitable, can be put aside and otherwise converted. In connection with single-bladed saw frames a patent was taken out a few years since by Messrs. Robinson and Smith for an improved swivelling and butting slide, which enables the frame carrying the saw to be driven at a high rate of speed, as, no matter what angle the connecting rod is at, owing to the swivelling arrangement, there is no undue strain on the saw frame or bearings. The saw employed is arranged to cut both ways of the traverse. In the United States, what is known as a 'Muley saw' is in use for making single cuts. It consists of a single reciprocating blade, tapered off somewhat from the points of the teeth to the base of the saw. It is of thicker gauge than those generally in use, and is strung without the aid of a swing frame, and is run at a much higher speed than the ordinary machines, generally some four or six hundred strokes per minute. In many of the American and French frames the swing or saw frame and other reciprocating parts are made of wood, to secure lightness as far as possible, and, contrary to English practice, the fly wheels are occasionally used as driving pulleys. In American deal frames the wood is usually fed by four plain rollers driven vertically, one pair acting as a fence or guide, the other pair being allowed to expand, or allow for any inequalities in the timber, by means of a spring, the variations in speed of feed being secured by a grooved wheel and paul, a ratchet wheel, or cone pulley and rack and toothed wheels. In addition to the roller and rack-feed motions for saw frames which we have noticed for cutting deals at a rapid rate, what is known as the chain feed is sometimes employed. This consists of one or more endless square-linked chains, according to the number of deals to be sawn. To these chains are fitted movable 'dogs,' which grip the ends of the deals. The continuous forward motion to the chains is obtained by worm and worm-wheel gearing, actuating drums toothed to correspond with the links of the chains and gearing into same. This, for small-sized frames running at a high speed, we consider a very useful form of feed. Through lack of power or other causes, it is sometimes necessary to drive timber frames independently of the other machinery or shafting. This is done either by attaching an engine directly to the crank shaft of frame, or fixing a steam cylinder at top or base of same, the piston rod in connection with side rods being coupled directly to the swing frame. By this method steam can be brought from a distance, or a small additional boiler provided. The cylinder is constructed so as to regulate the amount of steam used in proportion to the work in hand. The general details of these frames are usually of the ordinary type, and the whole is fixed on an extra large and heavy bedplate.

When, owing to water or other causes, it is impossible to dig far beneath the surface of the ground to secure the necessary firm foundation, frames are constructed to drive by a belt from above, the crank shaft, pulleys, &c., being placed at the top of the machine, instead of at the base. In these cases, in addition to a moderate foundation near the level of mill floor, it is generally necessary that the frame should be firmly fixed or stayed overhead to strong cross-beams, and, if possible, the end of the crank shaft supported by a strong sole-plate or bracket, built into the side wall. Where saw mills are of light construction, the frames are made self-contained—that is, the crank shaft is fixed overhead on a strong entablature, bolted to top of machine; this entablature is usually of box section:

the outer end of crank shaft is supported by two cast-iron columns, braced together, and stayed by additional diagonal stays from the base of columns to the top of main framing of the machine. Where it can be avoided, we do not recommend frames driven from above, as, amongst other drawbacks, as a rule, the vibration is found to be excessive. A considerable number are made counterbalanced with fly wheels at either end of crank shaft and the driving pulleys in the centre, motion being given to swing frame by two side rods; in this arrangement, however, provision should be made to fix diagonal stays, if found necessary. Fig. 6 illustrates a Frazer's equilibrium double deal and flitch frame by A. Ransome and Co., Limited.

These machines are designed to run at a high speed and are fitted with two separate swing frames which are worked from one double-throw crankshaft so arranged that when one is at the top the other is at the bottom of the stroke, and they thus counterbalance each other, enabling them to be run at a considerably higher speed than an ordinary deal frame, at the same time the necessity for a counterbalanced fly wheel is obviated.

Each swing frame is fitted with a separate feed motion, enabling two classes of work to be cut at the same time at different rates of speed if desired.

The deals are fed by means of a pair of vertical feed rollers, both of which are driven and provide a powerful feed. The crankshaft is fitted with a heavy driving pulley at each end to equalise the strain on the shaft.

In some deal frames of recent construction an adjustable friction-disc feed has been substituted for the ordinary cam-wheel feed, and forced lubrication for the crank-pin bearings has been introduced with very satisfactory results.

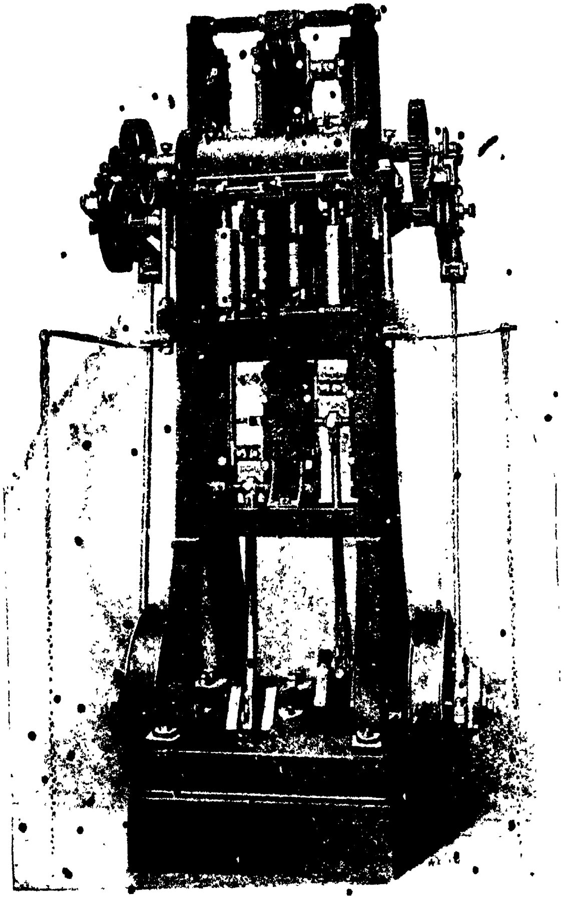

FIG. 6.—EQUILIBRIUM DEAL AND FLITCH FRAMES.

CHAPTER VII.

TIMBER AND DEAL FRAMES, ETC.—*continued.*

SEVERAL patents have recently been taken out for improvements in reciprocating saws, amongst which ma be mentioned one by Mr. Edwin Chabot, of Sout Norwood, dated 1877, who claims as novel, on behal of Ferrando Morel, of Barcelona, an arrangement fo sawing timber in such a manner that four thick plank may be simultaneously sawn up by four sets of saw carried in one reciprocating frame. It is described a follows: "I arrange the machine in such manner tha in place of the reciprocating frame carrying only on set of saws on either side of the travelling carriage, arrange it to carry two sets of saws, and I provid separate guides for each plank of timber, to be held u to one plank on each side of the carriage, the one bein pressed towards the travelling carriage, and the othe away from it, up to their respective guides. The guide can be set towards or away from their respective sets o saws without stopping the machine. The machine, a heretofore, is provided with a main driving-shaft, havin upon it a crank for giving motion to the reciprocatin saw-frame, and with rollers for supporting the planks and with a slowly moving carriage, actuated by a rac and pinion, for traversing forward the planks of timbe up to the saws. Provision is also made for setting th saws situated at one side of the traversing carriage to cut up a single plank of considerable width, whilst at the same time the saws on the opposite side are set to cut up two planks. The saws, as heretofore, are set to any desired distance apart, according to the number of pieces into which it is desired to divide the plank. By the above construction of machine, four different kinds of work can be performed simultaneously, instead of two, as heretofore.'

Mr. Samuel Worssam also in 1876 secured a patent for improvements in equilibrium saw-frames. These chiefly consisted in using two separate rack-feeds placed side by side, intermediate of the two saw frames, and placing the feed wheels both on the same side of the machine, thereby enabling the feed of each deal or plank to be regulated independently of the other, and enabling a single attendant to attend to both feed wheels from the side of the machine, thus doing away with the expense of a second sawyer.

Improvements in the general arrangements of the parts, and the mode of operating horizontal reciprocating saws for cutting boards, have recently (1879) been patented by Mr. Adam Knox, of Glasgow, by which he claims a greatly increased production with less power. His designs, although slightly complex, have considerable merit in arrangement; we therefore describe them somewhat at length. The improvements claimed are as follows:—

The general construction or arrangement and combination of the parts of wood-sawing machines or mechanism, of the horizontal reciprocating class with blade or band saw or saws, reciprocated on the periphery of segmental levers or on pulleys.

The carrying and actuating of a horizontal reciprocating blade or band saw or saws on the periphery of reciprocated segmental levers or on pulleys, either having an edge-rocking or curvilinear motion given to them or not, as desired, for the cutting of wood in horizontal sawing machines.

The carrying of the reciprocating segmental levers or pulleys with their saw or saws on fixed centres (either with or without antifriction pulleys) on vertical slides or guide frames, to give the different thicknesses of wood to be cut in horizontal sawing machines.

The giving of the edge-rocking action to the segmental levers or pulleys carrying and actuating horizontal reciprocating saws (in wood-sawing machines) by radial links, cams, or angled centres.

According to one modification and arrangement, in coupling the horizontal transverse reciprocating saw by its two ends direct, by buckles or other suitable couplings, to two broad, thin blades of steel or other equivalent elastic or flexible bands, so mounted on as to reciprocate over the upper periphery of two large strong but slight oscillating pulleys, or it might be duplex segmental pulleys oscillating vertically on strong studs projecting from the face of two slides mounted and worked simultaneously by screw spindles on strong vertical planed guide frames, with long bracketed sole behind on each side of the ordinary longitudinal carriage carrying the wood to be cut, and traversed on the main stationary bed frame, which may rest in front on the strong deep traverse frame, secured to the foundation below, and carried or branched up so as to be secured to the vertical slide guides or standards on each side, to stay or make the whole securely steady and rigid.

An equivalent broad elastic or flexible band is securely stretched on and between the under or lower peripheries of the pulley or segmental levers, one or both bands being fitted with tightening screws to adjust and put the proper tension on the saw blade and band below, to make the strains all equal and self-contained within the rocking frame, the carrying centres and eyes of the rocking pulley and segmental levers on which the strains come being made very long to sustain the strains with perfect steadiness and little tear or wear.

The two slide frames carrying the axle studs of the oscillating pulleys or levers are bound together by a strong bow frame above, with room for the log or wood to be cut to traverse under it, and brackets project down from it with slotted adjustable guides for embracing and steadying the saw on each side of the log or wood being cut. Thus the whole frame so bound together is carried and simultaneously raised or lowered by the vertical screws in vertical side guide-standards coupled by a transverse shaft and bevel wheels at the ends, either carried in bearings on the frame below, or it might be on a cross beam above, so as to set the saw to the proper height at which it is desired to make the cut into the wood, to give the required thickness of boards down from the top surface, which is usually first dressed off or formed by one cut of the saw through the log or wood from which the boards are to be cut, and which is fixed on the traversing table below the level of the saw drafts by the usual gripping side 'dogs' and tightening screws mounted on the table, which is traversed as usual by plain-running, edge-rimmed, and flanged wheels or side guide-rollers on the planed guides of the fixed bed frame.

The segmental pulleys and saw are oscillated or reciprocated by a long connecting rod attached at one end to a lateral or crank pin on one of the lower segments, and carried across the machine below the frame, with the other end connected to a shifting and fixing crank pin in an overhung disc or crank on the belt-pulley driving shaft, carried longitudinally in bush bearings either on the lower part of the stationary guide slide-frame at the other side of the bed plate and machine, or on the raising and lowering slides thereof, so as to rise and fall with the saw when desired, and fitted with compensating belt pulleys for taking up the slack of the driving belt when that is used for actuating the first-motion crank shaft.

The table carrying the log or wood is fed forward to the saw much in the usual manner by a toothed rack on the centre of its under side, actuated by a toothed pinion on the inner end of the transverse reversible driving shaft, actuated at a slow speed to traverse the carriage forwards by a screw wheel on its outer end at the driving-gear side of the machine, turned by a screw on one end of a longitudinal cone pulley feed-shaft, shifted up out of and into gear by the raising or lowering of the screw into gear with the screw wheel, but this is also fitted with a bevel wheel, and pinion, and hand wheel or hand crank-shaft for feeding the table backward and forward by hand.

For running the table back at a high speed, for making a fresh cut (or it might be forward when required), an extra belt pulley feed-shaft may be employed, with two loose bevel pinions and clutches on their inner faces, and a shifting and reversing clutch box between them, the bevel wheels gearing into a bevel wheel on the extreme end of the transverse feed-motion shaft before mentioned, the clutch box being fitted with an engaging and disengaging hand lever, so as to either throw this high-speed feed motion out of gear or into the back or forward gear, as desired.

The reciprocating motion given to the saw may either be that of a straight line in the cut, or otherwise it may have a curvilinear motion, preferably entering or cutting into the wood deeper and deeper from the side the saw is traversing for the time being, making the face of the cut of a convex curve, and this motion may be given to the saw either by radius bars or cams attached to studs or centres on the deep eye of the segmental pulleys and to the slide plate, so set as to lengthen on the in stroke of the saw, and shorten on the out stroke thereof, and thus slide the pulleys by their eyes to and fro on their axles; or otherwise fixed or movable cams might be fitted on the fixed or movable axes of the segmental pulleys for the said purpose of giving this curvilineal motion to the saw.

When it is desired to give the saw a long reciprocating stroke with a short crank or reciprocating motion of the connecting rod, the lower segments of the saw pulleys (to which the connecting rod is coupled), instead of being of equal radius, may be of less radius than the upper to which the saw is connected; and in addition to (or instead of) the flexible or other band connected to the lower segments on opposite sides of the machine, a connecting rod may be attached to these by lateral studs in them on the opposite side to that on which the actuating connecting rod works.

Although only one saw has been described as fitted on the upper segments or arms of the reciprocating pulleys, it will be understood that two, three, or more may be so fitted, each stepped and coupled below the other on segments or pulleys of a less radius than the first, corresponding to the different thicknesses of the boards to be cut.

The pulleys or segmental levers carrying the saws, when made in the form of segments or sectors, might be made of solid edge wood, or built, or of radial arms and side stays or tie bars of light malleable iron, to give great strength with lightness.

The connecting rod also might be made of wood or light side wrought-iron bars for the like purpose, and the crank disc would have a counterbalancing segmental block, or a box formed on it for having lead filled into it to balance the weight of the connecting rod.

In designing timber and deal frames, care should be taken that the main framing of the machine should be sufficiently strong to withstand the heavy strain necessarily put on it when running with a large number of saws, especially when sawing hard or frozen wood. For many years these main framings were constructed of wood, the uprights being fastened to the cross-beams of the saw mill itself. A considerable number of these wooden-framed machines are now in use in the United States and Canada, and do a large amount of work. In small-sized frames for cutting deals, &c., the standards and top and foundation plates are now often made in one casting. This certainly secures great strength and compactness, but they are hardly so handy for repairs, and are more difficult to manipulate, in the first instance, when on the planing machine. In all reciprocating machines, the working parts should be constructed to combine *strength* with *lightness* in the greatest possible degree. In the working or swing frame which carries the saws, this is of the greatest importance. It is found that steel of hollow section is the most suitable material to employ, as it is capable of withstanding with ease the immense strain that is put on the swing frame when working a large number of saws in hard or wet wood. This strain is very great, amounting to at least five or six tons per saw. The total compressive strain that the swing frame has to bear should therefore be calculated by the maximum number of saws it is proposed to work, allowing a considerable margin for contingencies, as it is found when a large number of saws are used, and the strain is thus multiplied many times over, that unless the steel is of ample section, the cross rails will spring considerably.

As regards the crank shaft—which should be made of good wrought iron, and free from seams—the best form to use for general purposes is the double or bell crank, with a bearing placed well up to the crank on either side, and a third bearing on the outer side of the driving pulleys. By this arrangement frames are found to be much steadier in work. Cranks bent by hydraulic pressure have lately come considerably into use; and when manufactured in this manner they possess several features which render them considerably stronger than the ordinary 'block' crank. The gradual pressure of the hydraulic press as it forms the throw of the crank forces the ends of the shaft inwards, and the fibre of the iron is not strained or broken, and it runs completely round the throw, thus rendering it equal in strength to the other parts of the shaft. In the ordinary block crank the fibre of the iron runs across the web, and is much weakened and damaged when the throw of the crank is cut out, and a fracture is very generally found to take place in this web. The connecting rod should be arranged to take hold of the saw frames by means of rods on either side at about the centre of same, as strength and ease in working are gained, and less depth of foundation is requisite. As regards the feeding arrangements, they must of course be adapted to circumstances. Top pressure-rollers for deal or flitch cutting should work independently of one another, so that two pieces of unequal depth can be sawn at the same time. The bearings in which the swing frame works should be adjustable, and by preference made of phosphor bronze. A very good plan is to have an opening in either side of the uprights, and the bearings fixed nearly flush with the outside of the frame; they are thus easily got at for repairs, lubrication, &c. When frames are run at high speeds, the connecting-rod bearings should be of phosphor bronze, and especial care should be taken as to their lubrication, as the friction is very considerable. The cross heads should be forged in the solid, of best fagoted scrap-iron. We purpose noticing the buckling, sharpening, and setting the saws elsewhere.

The double horizontal saw frame illustrated by fig. 7 is a very well-known type, built by Messrs. Thomas Robinson and Son, Limited. It is greatly favoured for cutting logs of costly timber into boards and panels—its special use being for the finest sawing, where quality of work is of more importance than a large output.

The double type saw frame not only possesses all the advantages of the single-bladed frame for the above classes of work, but is capable, of course, of turning out considerably more work with less wear and tear, and with only a small increase in the amount of power required for driving, owing to the working parts counter-balancing each other.

The saw frames in the machine illustrate each work in separate slides, carried on a cross-rail, which is raised by power on two vertical turned pillars. The weight of the saw frames is supported on ball-bearing thrust blocks, which greatly facilitate its easy adjustment.

The front saw is only a few inches in advance of the rear one, so that the saws are working together almost immediately at the commencement of each cut. The distance between the top saw and the under side of the cross-rail is 7½ in., and the greatest depth that may be cut between the two saws is 6 in. By removing the back saw blade a depth of 13½ in. can be cut by the front saw.

The working frames are built of steel, together with the cross heads and adjustable slide blocks. They are driven from a two-throw crank shaft, having the cranks set at opposite centres. In the larger sizes, the crank shaft bearings are mounted in slides, so that the crank shaft can be raised or lowered for cutting large or small logs.

The vertical pillar nearest the crank shaft is of small diameter, so that the connecting rods working the two saws can pass on either side of it; thus the distance between the two saws is kept as short as possible, and the saws are easily accessible for putting in or taking out of the frame.

The rate of feed is variable, and can be started, stopped, and reversed at a high rate of speed by means of the controlling levers, and at any period of the cutting the rate of feed may be altered.

CHAPTER VIII.

PLANING AND MOULDING MACHINES.

After the timber has been converted by means of circular or straight saws from the forest tree into deals or boards, the internal economy of a saw mill is, or should be, so arranged that they naturally pass on to the planing, moulding, and other machines, for rapid conversion into articles of daily commerce. Planing and moulding machines must, after saws, be considered the most important of wood-working machines; and as their action and manipulation are very similar, and are oftentimes combined in one machine, we purpose taking them together. Before proceeding to machines driven by steam, it may be of some interest to notice briefly a few of the different kinds of plane irons worked by hand, as it will enable us to judge better of the principles involved and the work required to be done by a planing machine. A plane may be briefly described as a tool used by those who work in wood to produce straight, flat, and even surfaces in that material. Its construction and action are, however, too well known to need description here. There are a considerable number of planes, which are known by different names, according to their size and the purposes to which they are applied. Those chiefly in use are the jack plane, trying plane, shooting plane, long plane, and smoothing plane. These are usually called bench planes. There are also rebating planes for forming rebates, the straight block for straightening edges, sash planes, grooving planes, &c.; also many other tools, usually called moulding planes or irons. These are capable of producing at a slow rate a great variety of ornamental mouldings; beads, hollows, rounds, ogees, and ovolos are those most generally worked by hand, where small quantities and very simple ornamentation is necessary; but at the best hand moulding is a very tedious and costly process, especially when we consider that a moulding that would take a competent workman some hours to produce can be completed on a good machine in less than *one minute.*

Planes are necessary for the manipulation of almost all kinds of work in wood, and those intending using them, either for business or pleasure, should first of all understand their construction, and how they can be best applied; we cannot, however, here give them more than a brief comment. The jack plane is used for taking off the rough and prominent parts from the surface of the wood in coarse shavings; the plane iron is fixed in the stock so as to make an angle of 45 degrees with the face of the plane. All other planes are more or less similar to the jack plane, differing only in dimensions and smaller details. The trying plane is longer than the jack plane; it is fitted with two handles, and the iron is set 'finer,' thus cutting a thinner shaving. The mouth of the plane is also much narrower. The shooting plane is the longest and most correct plane used, and is employed after all the others, chiefly in shooting the edges of boards that have to be joined together. The work of these and all other planes, owing to their slow production and necessary costliness, it has been found necessary to supersede as much as possible, and the result is that numerous machines driven by steam power, and adapted for all classes of work, have almost entirely taken the place of hand labour; therefore, where considerable quantities of one particular article or pattern are required, and even when very small quantities are used, it is found much cheaper to purchase from a manufacturer than to work them by hand. This can be easily understood, when we consider that the cutting action of a carpenter's plane can be estimated to travel, say, at some 75 feet per minute, whilst the cutting edge of the irons of a planing machine travels some 4,000 feet in the same time. The principles involved in the two operations, however, differ essentially. In the case of the carpenter's plane, pushed forward by hand, a reciprocating motion is obtained, whilst machine cutters, as a rule, have a revolving or rotary motion; some, however, are constructed, for special purposes, with fixed cutters, the action of which resembles the hand plane reversed, the wood moving instead of the plane iron.

The first reliable record we have of an attempt to supersede hand planing by machinery is contained in the patent of Hatton, dated 1776; but this seems to have been only a series of crude mechanical ideas, which were never acted on or carried into any practical effect. In fact, the idea or invention can hardly be dignified by the term 'machinery.' As Rees says in his Encyclopædia, we take it that machinery, or mechanical means to dispense with or modify the use of hand labour, must fulfil at least one of the following conditions: viz. 'that it increases the effect of a given finite power, so as to overcome a resistance that is greater, and would otherwise remain unchanged; to accommodate the direction of the moving force to that of the resistance to be overcome; and to regulate and modify a variable force, so as to produce a constant and uniform effect'—these are the principal ends to be accomplished by machinery. If this was more fully borne in mind by patentees of the present day, some thousands of the so-called inventions would never have been perpetrated.

Sir Samuel Bentham, in 1791, patented a planing machine, but, notwithstanding the ingenuity of the inventor, it did not come into general use; it was, in the first place, intended to be worked by hand power. The principal object claimed by the patent was the adjusting of the plane or cutting iron, so that it could not but perform the operation intended, without requiring any skill of the workman, thereby rendering a common labourer as serviceable as the best joiner for this purpose. With this view, the plane iron was made the full width of the board, and on each side of it were fixed fillets, which projected below the face of the plane just as much as it was intended to reduce the board in thickness, serving also to guide the iron sideways and to gauge the thickness.

The plane was kept down by its own or additional weights, when necessary, which latter were so contrived as to be capable of having their position shifted during the time the plane was making the stroke, the pressure at first acting forwards, and lastly on the hinder part, to prevent the fore end dipping down the instant it leaves the board. By another contrivance, the plane was lifted up on its return, so as to clear the cutting edge from the wood. This was effected by a piece of wood, which acted as a handle to the plane, and to which the power was applied. It was placed, with this view, upon an axle extending across the width of the plane, and carrying on each side a short lever, provided with rollers at their extremities. The handle projected upwards from the plane, which, being forced forward by it, assumed an inclined position, as also did the short levers, so that their rollers then rose above the cheeks of the plane; but when the latter was drawn back into an erect position, the levers moving with it, their rollers projected beneath the cheeks of the plane, and raised it off the bench, the plane being supported by them on its return.

In cases where the boards to be planed were winding and irregular, 'dogs' furnished with teeth gripped the board on either edge and held it firmly between them. These 'dogs' were arranged to rise and fall, to suit different thicknesses of boards. Where very thin boards, which were liable to spring, had to be planed, rollers loaded by levers and weights were used, as they are even at the present day. Arrangements were also made for planing feather-edged boards. The above machine had a reciprocating motion, which was secured by a crank and wheel, turned by manual labour; the plane iron moved over the wood, and the motion generally was intended to be an imitation of the carpenter's plane, as worked by hand. It was not, however, a success. It might have been put in motion by water or other power, but we believe it was never worked usefully; as an early attempt, however, to overcome the labour of hand planing by mechanical means we think it deserving of notice.

In the patent taken out by Sir Samuel Bentham in 1793, in addition to numerous other ideas, he claims the invention and application of an improved rotary planing and moulding machine.

The chief inventions relating to planing and moulding machines claimed by Sir Samuel Bentham in his patent of 1793, before referred to, are as follows:—A cutter 'block' or roller, in which planing or moulding irons can be fixed, with arrangements to rise and fall same to suit varying thicknesses of wood. He also says to gain time cutters may be applied to different sides of a piece at once, and such of them as make parallel cuts may be mounted on the same spindle. In the fifth section of the specification relating to rotary tools for wood-cutting he claims 'The idea of adapting the *rotative* motion of a tool with more or less advantage, to give to all sorts of substances any shape that may be required, is my own, and, as I believe, entirely new.'

In reference to mouldings he says, 'If the circumference of a circular cutter be formed in the shape of any moulding, and projected above the bench no more than is necessary, the piece, being shoved over the cutter, will thus be cut to a moulding corresponding to the cutter that is the reverse of it, just as a plane iron cuts the reverse.' In addition to numerous other inventions and improvements relating to all kinds of operations for working wood, Bentham in this patent describes the process of preparing dovetail joints with conical cutters, a plan which is still in use. The more you peruse this extraordinary specification, the more wonderful it appears that the inventive genius of the man could grasp and set forth so tersely so many original ideas at the same time—enough, in fact, to make twenty patents of the present day. Certainly Bentham may be said to have originated a very large share of the principles connected with wood-working machinery now in operation.

The next great improvement in planing machines was made by Mr. J. Bramah, of London, who took out a patent in 1802 for machinery, for the purpose of producing straight, smooth, parallel surfaces and curvilinear surfaces, on wood and other materials, in a manner much more expeditious than can be performed by the use of axes, saws, planes, and other cutting instruments used by hand. This specification is very voluminous. The chief points that seem to have been claimed are that the wood to be planed is made to move in contact with the plane iron, instead of the plane iron being carried over the work by hand, in the usual way; that the cutting tool be made to travel across the work in a square or oblique direction, except where the use of a fixed iron is necessary. He claimed also the application of roughing out and finishing irons fixed in movable frames, with screw adjustments to suit thickness of timber. These irons were arranged so as to work at variable speeds, according to the material being operated on.

Acting on and improving these ideas, Bramah erected for the Government at the Royal Arsenal, Woolwich, a heavy rotary planing machine, which contained several very novel features, chief amongst which was the arrangement of a hydraulic or hydrostatic press, to work the movable carriages on which the wood intended to be planed was supported. Its operation may be described as follows:—The machine was fixed on a solid bed of brick or stone work, rising about one foot above the floor line. Iron slides the whole length of the machine (some 40 feet) were fixed on these foundations; these slides were made to incline some half-inch from the horizontal line towards the one end of the machine; at this end, beneath the machine, was fixed the cylinder of an hydraulic or hydrostatic press, having two entrance pipes, one at each extremity. The piston rod of this press was furnished with a rack, which worked a pinion under and attached to a wheel. Round this and three smaller wheels passed an endless chain, which was regulated and kept to its work by means of an adjusting screw. A chamber containing the condensed or compressed water was fixed near, and the water was conveyed by pipes to valves or cocks, which were so arranged that the water entered one end of the cylinder, and urged the piston forward, and the rack working on the pinion under the wheel gave motion to the chain, and the travelling carriages which supported the wood to be planed attached to it. The water was then stopped, and permitted to enter the cylinder at the opposite end, thus forcing the piston and carriage back to its original position, the waste water in the meantime being allowed to escape; this gave a reciprocating motion, similar to that of the piston of a steam engine. The travelling carriages, being attached to the chain one at a time, were thus hauled backwards and forwards under the rotary planing disc. This planing disc was fixed at the end of a strong vertical spindle, which in its circumference was pierced with thirty holes, in which were fixed twenty-eight gouges or cutters and two plane irons. The disc was kept in a horizontal position by diagonal braces, and was made to rotate at the rate of about 90 revolutions per minute, by means of bevel gearing, which was set in motion by a steam engine. Thus the general action of the machine is pretty clear, as while the carriages holding the wood passed from one end of the two slides to the other by the action of the hydraulic press, as explained above, the planing disc was put in rotation, and so adjusted that the gouges and plane irons caught the surface of the wood as it passed under it. These gouges were arranged at different distances from the centre of the disc, and took the rough surface from the wood, and were followed by the two planing or finishing irons, which rendered the surface plane and smooth. The planing disc was sustained and adjusted to suit different thicknesses of wood, by means of hydraulic pressure immediately under the control of the workman.

The action of the above machine would doubtless, in the present day, be considered very cumbersome, but as an early attempt to supersede hand labour by mechanical means, and considering the resources at the command of the engineer, it must be conceded that the inventive genius of its designer was of the highest order.

In 1803 a Mr. Bevans obtained a patent for a machine for cutting or 'sticking' mouldings, making rebates, grooves, and planing flat surfaces of small width. This, like Bentham's first patent, was an imitation of the action of hand labour in planing. A number of moulding irons were fixed, either singly or side by side, according to the work to be performed. In a frame or box these irons were arranged so as to form the mouldings required. The wood was fixed on a bench, and the box of irons made to pass over it lengthways by a connecting rod, communicating with machinery capable of giving a reciprocating motion. The crank which gave the reciprocating motion was arranged to vary the length of its stroke according to the work required to be done. This was done by making the arm of the crank to pass through a mortise in a strong box fixed on an axis, and allowing it to slide in the said box. Set screws were used to fix the length of the stroke as wished.

The irons were loaded to keep them in contact with their work by a long beam of wood, set up on end upon the sides of the box, and connected therewith by being divided into two cheeks, which at the lower sides were formed to an arc of a circle, and united to the box by chains, in the same manner as the beams of beam engines are connected with their piston rods. The upper part of the beam was made to pass always through one point by sliding between friction wheels, or otherwise in a tube hung on two pivots perpendicularly over the centre of the work, and at such height as might be most convenient for the length of the stroke required.

The connecting rod from the crank before mentioned was jointed to the upright beam, near its lower end, and by this means the motion was given to the box of irons, the chains and arches at the bottom allowing it in all positions to preserve the plane horizontal. To guide the box of plane irons in a rectilinear motion, and also to bear them off when they had been reduced to the depth required, fences were used, which were irons sliding perpendicularly in tubes or sockets in the box or frame, and clipping a tongue or guide fixed in the direction of the required stroke in the frame supporting the bench.

CHAPTER IX.

PLANING AND MOULDING MACHINES—*continued.*

FOLLOWING Bramah's patent, several improvements were introduced by Burnett, Paxton, Poyer, and others; but it was not till the year 1827 that planing machines were brought into extended practical use in this country. In this year Mr. Malcolm Muir, of Glasgow, invented and patented a machine of most improved construction. Its mechanism contained many of the most essential points as in use in planing machines of the present day; in fact, succeeding makers, although introducing modifications of their own, seem to have entirely accepted it as their model. As its invention is [redacted] interest to engineers, and marks an era in wood-working machinery, we give an illustration of Muir's first machine, with a description of it as given by Hebert.

'This machine, invented by Mr. Muir, of Glasgow, has for its object the preparation of complete flooring boards, with extraordinary despatch, and in the most perfect manner; the several operations of sawing, planing, grooving, and tongueing being all carried on at the same instant, by a series of saws, planes, and revolving chisels.

'Fig. 8 represents a plan of the machine, slightly modified, to render the construction more easily understood by the reader. The machinery is adapted for the *simple planing* of boards, as well as the preparation of *square-jointed* or *plain-jointed flooring.* We shall commence our description by an account of those parts which constitute a simple planing machine, and then proceed to describe the apparatus by which it is adapted to the preparation of jointed flooring. The planing machine consists of a perfectly flat and straight bench *d d d*, which should be at least twice as long as any board intended to be prepared upon it. This bench is made fast to a block of stone *c c* or other solid matter, which, together with a suitable framing, serves to keep the machinery as firm and steady as possible. Along one side of this bench is a raised guide *e e*, which extends as far as the circular saws *i*, *i*; but only a part of it is shown in the figure, in order to bring some other arrangements more into view. About the middle of the bench a metallic plate *a a* is let in flush with its surface, which forms a durable stock for the plane irons; these plane irons are of the usual form, but of greater breadth than the boards to be planed. The projection of their cutting edge is effected and regulated by screws, and the number of plane irons employed at a time is determined by the degree of finish required for the surface of the boards; three plane irons are, however, generally used, as shown at *h*, *h*, *h*, the dark spaces being the mouths of the planes; from this it will be seen that it is the lower side of the board that is planed, and the shavings are delivered under the machine. An endless pitched chain, having catch hooks at convenient distances, takes hold of the boards as they are put into the machine in succession, and drags them along the bench; the edge of one of the sides of each board passing under a rebate in the

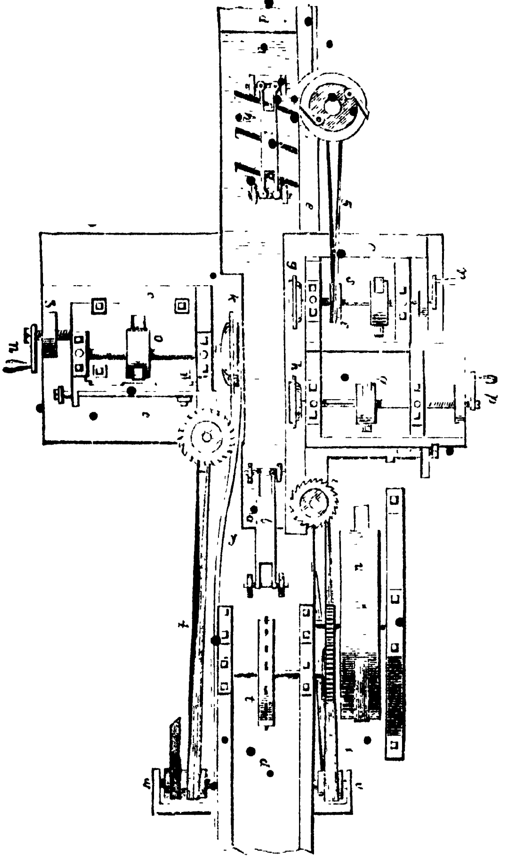

FIG. 8.—PLANING MACHINE PATENTED BY MUIR, A.D. 1827.

guide or fence (as shown in the figure) prevents the board from bending upwards by the action of the chain, while it is pressed down to the plane irons by springs or weighted levers, as seen at *b*, *b*, which are mounted upon antifriction rollers, the axles of which are so inclined as to cause the boards to be uniformly driven against the fence and to pass in a straight line through the machine. Motion is given by a band from a large revolving drum, placed above the machine (not shown in the figure), which communicates with the drum *u*, upon the shaft of which is a pinion that drives the toothed wheel *j*; the axis of the latter carries the pitched rigger *t*, round which the endless chain is passed, and stretched in a parallel direction with the bench, by passing over the pulley *z*, at the opposite end of the machine; at this place only a small piece of the chain is brought into view, as the introduction of the whole of it would hide or tend to confuse some of the other parts of the apparatus. The pulley *z* is mounted upon a tightening frame *y* which moves upon a joint at the lower end, the tension being increased or lessened by the wedges 1, 1, or by regulating screws. The parts we have thus described constitute a separate machine for the planing only of boards. [illegible] preparation of plain or square-jointed flooring boards, the following additional apparatus is brought into operation. A part of the fence *e* is slightly hollowed from the direct line of the bench, to admit of projecting inequalities in the edges of the boards; these are removed by irons or cutters fixed on a horizontal revolving plate *f*, the periphery of which enters an aperture in the fence *e*; and it is on the edge of the board presented to this side of the machine that a tongue or feather is formed when required. To produce this effect two circular saws, *g* and *h*, are used, one of which, *g*, revolves under the board, and cuts it upward; the other, *h*, revolves above the board, and cuts it downwards, to such a depth only on each side as to leave a tongue or feather of the required thickness uncut. By the progressive motion of the board it next passes under the operation of two circular saws *i*, one only of which can be seen, as the other is directly underneath on the same spindle, and separated only by a ring or washer, which is of the same thickness as the tongue. These saws, acting horizontally, or at right angles to those at *g* and *h*, cut off the superfluous wood, and leave the tongue projecting from the board completely formed. The opposite edge of the board is cut parallel to the other by a circular saw *k* revolving vertically, which is called the "*breadthing*" saw; a guide fixed to the head of *o*, which supports the spindle of this saw (but which cannot be seen in the figure), is so placed as to conduct the superfluous pieces, separated from the boards by the saw *k*, underneath the circular saw *l*; the slips are thus removed out of the way of the latter saw and preserved. The saw *l* revolves horizontally, and is called the "grooving saw;" it is considerably thicker than ordinary circular saws, and has long teeth to admit of their receiving a "set" to cut out the whole of the required groove at one operation. The spindle head which carries the grooving saw is adjusted and fixed by screws to a bracket attached to the head *o*, the latter being placed in slides, which keep it steady, and conduct it in a parallel direction when moved to or from the bench. All the parts that operate on this edge of the board being thus connected, advance or recede together. This movement is effected by means of a screw fitted with collars to the fixed puppet 3, and working in a nut in the back part of the head *o*; the screw is turned by the handle *n*, and an index on the head *o* points out the relative position of the circular saw *k* with respect to the other side of the machine, and consequently indicates the various breadths of the finished boards by pointing to a divided scale of inches and parts fixed upon the block *c*. All the saws are fixed on to the spindles in the ordinary way, by screws, nuts, and washers; but the spindles are considerably thicker than usual, to admit of their being fitted with cutters or irons, which, by cutting horizontally, rebate the superfluous thickness of the board to a sufficient extent from that part which is destined to form the under side of the floor in all flooring boards. The heads, which carry the vertical saws *g*, *h*, are placed on slides fixed to the block *c c c*, their horizontal position being adjusted by regulating screws, worked by the handles *p* and *r*, and their spindles elevated or depressed by proper adjusting screws. Motion is communicated by endless bands from a large drum wheel above the machine, such bands embracing all the vertical saw pulleys, and also the rigger or pulley *w* [illegible] intermediate shaft *v w*; and this intermediate shaft, by means of half crossed or twisted bands 4, 4, gives motion to the horizontal saws *i* and *l*. The circular plate or plane *f* is also impelled by another half-twisted band 5, from a pulley 6, on the axis of the saw *g*. The power which impels the whole machine is derived from a steam engine or other prime mover applied to the shaft of the large drum wheel before mentioned.'

A number of these machines were made and erected by Mr. Muir in Glasgow and other towns, and were in operation for many years. Mr. John McDowall, of Johnstone, near Glasgow, made a number of machines on Muir's model, and afterwards introduced several modifications and improvements of his own, for which he obtained a patent in the year 1836. The chief of these improvements consisted in the introduction—in the place of the endless-chain feed, which, when planing thin stuff, had a tendency to tear the wood—of two pairs of rollers at the front and back of the machine, to feed the boards through the cutters, by means of frictional pressure. The rollers were turned and made to act like the rollers of a calendering machine; the upper ones were held down by weighted levers, which gave them an increased grip on the wood which passed between them. The rollers were found to answer their purpose well, and the thinnest boards were carried through the machine without difficulty. Another improvement was the introduction of a new method of cutting tongues and grooves on the edges of the boards. Muir employed four saws for this purpose, one cutting up, another cutting down, and two cutting in, so that two strips are cut off the sides, leaving the tongue or feather in the centre; this plan did not act well when working on thin wood. Mr. McDowall substituted a set of rotary cutters fixed on vertical spindles; these cutters were made the exact size of the tongue or groove required, and being placed on either side of the machine in brackets working on a slide, could be adjusted by means of a screw and hand wheel to suit varying widths of boards; this plan is in use at the present time. Mr. McDowall also, a few years later, introduced several other modifications in these machines, including a silent feed motion with differential action, and an arrangement of combined roughing and finishing cutters for thicknessing. The feeding motion was a decided novelty. As the deal entered the machine to be cut it passed beneath a set of feed cams, which nipped the wood and carried it continuously forward. This feed arrangement consisted of horizontal traversing plates of metal, tongued at opposite ends, to slide freely in corresponding grooves in the top plates of the standards, and upon these plates a pair of vertical parallel standards were attached; these standards were connected at their upper ends by a light cross-bar. Each standard was slotted down its centre, to receive and guide the traversing nut-bearings of the cross cam-spindle. A screw was passed down from above and through the nut-bearings, so as to allow the cam spindles to be set up or down. Each cam spindle had an eccentric cam loosely hung on it by an eye, the cam eye being fixed against an adjustable collar. Thus arranged, this nipper feed formed a complete traversing frame capable of free horizontal movement.

The primary movement was given to these nipping feeders—of which there were six altogether, three at each end of the machine—by a toothed pinion on the first motion shaft. This pinion geared into a large toothed wheel set on a cross shaft, and carrying a second pinion in gear with a second spur wheel, fast on the actuating cam-shaft. On this shaft three separate cams or differential eccentric pieces were keyed. Over the periphery of each cam was set an anti-friction pulley, carried on the horizontal arm of a bell-crank lever, the three bell cranks being carried loosely on a stud shaft. The long vertical arms of these bell cranks were connected by eyes at their lower ends to their respective rods, which were severally linked by end and intermediate eyes to the bottom of each of the nipping frames. The three cams were so set at starting that they each acted at different periods of the revolution of their shaft in such a manner that an uniform feed motion was given to the board passing through the machine. This method of feeding the timber, although ingenious, had several objections, and has long been disused, but it certainly deserves a passing notice.

About the year 1847 several improvements in the method of operating planing and moulding machines were introduced in America by John Cumberland and others. A great number of the machines hitherto constructed in America were built with cutters working on a vertical axis, as first patented by Bramah in this country in 1802. Numerous alterations and modifications were, however, introduced, which rendered this class of machines much less complicated and cumbersome; among these may be noticed an improved reversing gear fitted to the travelling table which passed beneath the rotating cutters. This consisted of two spur wheels, one twice the diameter of the other, gearing into a worm wheel. The opposite ends of the shafts upon which these wheels were keyed, rested on a screw, so centred that when one is raised the other is lowered; small pinions upon them are then brought into gear alternately with the rack fixed on travelling table as required—the larger wheel giving the slow forward motion, and the smaller the quick return motion, to the travelling table carrying the wood to be planed.

CHAPTER X.

PLANING AND MOULDING MACHINES—*continued.*

PREVIOUS to our Exhibition of 1851 considerable progress was made in the United States in planing and moulding machinery. Its rapid development was, however, much retarded by the tyrannical operation of the holders of several patents, chief amongst which was that known as the 'Woodworth planer.' This patentee, it seems, claimed in America the introduction of the combination revolving cutter-blocks and roller-feed motion for planing wood. The validity of this patent was contested for many years. One part of the patent, viz. the roller-feed arrangement, was known in this country many years before. (See patents granted to Charles Hammond, London, 1811, and Burnet, for improvements in machinery for planing wood, 1839.) Notwithstanding these difficulties, Messrs. C. Rogers and Co., of Norwich, Sellers and Co., of Philadelphia, Fay and Co., of Cincinnati, Whitney, Woods, and other American houses, added materially to the advancement of this branch of manufacture, as exemplified in our Exhibitions.

American planing machines are chiefly constructed after two models, known as the Woodworth and the Daniels planing machines, though of course modified or combined according to requirements or nature of work.

The Woodworth machine was patented some forty years since, and its functions answer almost entirely with our own roller-feed machines combined with revolving cutter-blocks. The Daniels planing machine answers in its action to the one invented in this country by Bramah, which we have before described, it having a horizontal arm fitted with a cutter at either end, and is made to revolve over the timber as it passes beneath fixed on a table which is driven by a rack and pinion or other suitable gearing. The travelling bed of the Daniels machine is sometimes combined with the revolving cutter-block and feed rollers of the Woodworth; it then answers to our trying-up machine with an additional roller feed. This combination has the double advantage of being both a surface dresser and being able to plane timber out of 'wind.'

The Daniels or traverse planing machine is chiefly used in the heaviest class of railway or waggon work, or where timber is twisted or warped, and where it is necessary to take it out of 'winding.' In point of fact, machines constructed with a travelling table are the only true planing machines. The arm or disc in which the cutters are placed revolves in a horizontal plane, and the cutters attack the wood at right angles to the grain. With this class of machine no difficulty is experienced in working any kind, size, or condition of material. When very thin stuff has to be planed, weights or pressure rollers are used. The main framings of these machines are usually constructed in America of wood; the table, however, travels on a planed cast-iron bed. The cutter arm has vertical adjustment to suit varying thicknesses of wood, and the cutters are in operation during either traverse of the table.

The Woodworth planing machine, with its various modifications, possesses many features of interest, and some of the machines constructed by the leading American houses are extremely complete in their every detail. A short description of one, with additional improvements patented by J. A. Fay and Co., of Cincinnati, in 1862 and 1868, may not be out of place. The machine under notice is of recent construction, and one of the heaviest of its class.

The cutter blocks are made of wrought iron, and arranged to carry two, three, or more planing irons, and are fitted with steel lips, which form a back, to the ordinary iron, similar to the hand plane. The journals to carry the cutter blocks are of steel, proportioned in diameter to the weight of the cutter block and power of the machine. The bearings are made in length about five times their diameter, and lined with anti-friction metal; they are fitted with self-oiling boxes. Machines which are also arranged for moulding are fitted with an adjustable swinging pressure bar. The horizontal cutter-blocks have vertical screw adjustments. The vertical or side cutter-block spindles are made with three wings and of gun metal, and are fitted with a patent clip for matching, and constant lubrication is especially secured to both vertical and foot-step bearings. The vertical cutter-block spindles are fitted to a frame arranged with vertical adjustment, and can be lowered beneath the bed of the machine when it is required to use it as a surface planer only. The feed rollers, of which there are four or six, according to the size of the machine, are of large diameter, and are all driven in pairs by expansion toothed gearing, which 'gives' to uneven timber about three-fourths of an inch in 24 inches, and they are adjustable to different thicknesses. They are also arranged with a dead-weighting attachment, acted on by levers placed beneath the machine, and fitted in pivoted bearings, thus securing an equal pressure when working irregular timber. The upper cutter block is fitted with a spring pressure roller before the cut, and a yielding pressure bar after, which effectually resists excessive vibration of the wood when under the action of the cutters. This pressure bar is easily adjusted and is fitted with a gauge. The bottom cutter block is so arranged that the discharging roller carries the timber right through. These rollers can be swung out of the way when the bottom cutter block requires any alteration.

For gauging the depth when cutting beads a patent attachment is fitted into the pressure bar over the under cutter block, which gauges from the face of the board being worked. A roller guide for keeping the timber up to the fence is also fitted, together with changes of feed for hard or soft wood, which is started or stopped by a double pulley-feed belt-tightener. All bearings are fitted with large oil chambers, and the gearing with guards. Fast and loose pulleys of varying diameters are fitted to the countershaft. It will be gathered from this short description that the modern American Woodworth planer, in the completeness and easy adaptability of its many details, is a wood-working machine of the most advanced type.

In connection with planing machines, in addition to the ordinary method of feeding by geared rollers, the endless revolving apron or flexible chain bed feed is used considerably in America. This was invented by James Farrar some five-and-twenty years ago. It consists of a series of cast-iron slats or bars flexibly connected together, and made to revolve over rollers at either end of the machine by suitable gearing. It passes under the top cutter-block, and the bearing surfaces over which it slides are usually made of chilled iron ground smooth. The usual pressure rollers keep the timber firmly on the apron. For surfacing purposes it has some advantages, and is a rapid and powerful feed, but requires considerable care in its manufacture and manipulation, as the heavy friction to which it is subject, unless carefully guarded against, would necessarily cause its early deterioration.

Amongst the other American planing machines may be mentioned those of C. B. Rogers and Co., and B. D. Whitney, both of whose machines possess some interesting features. In one of Whitney's machines, especially adapted for re-finishing or scraping hard woods, the finishing cutters are fixed at right angles to the wood in movable drawers, and the wood is forced over them by powerful feed rollers. (See illustration, fig. 10).

Following our Exhibition of 1851 Mr. Samuel Worssam, of London, constructed a planing machine with roller feed which embodied several novelties. In the place of a larger number of small rollers he used two pairs only, of extra large size—some 2 feet diameter, we believe—and turned smooth on the surface; these rollers were driven by heavy spur gearing. The timber was operated on all four sides, the under cutters were placed between the first and second pair of feed rollers; these cutters consisted of one pair of revolving cutters for 'roughing out,' and two fixed cutters, set at an angle of 45 degrees; and, projecting slightly above the bed of the machine, these cutters gave a finishing, smooth surface to the wood. These fixed cutters were fitted into cast-iron drawers, which could be pulled out and replaced as required. The wood was held down on them by means of weighted levers, and the whole arrangement was very compact. Mr. Worssam also brought out, a few years afterwards, a machine, on Bramah's principle, for surfacing and squaring up timber; it was, however, smaller and less complicated. In place of the ordinary gouges or cutters, Wilson's patent cutters were used (patented 1857). These consist of cylinders of cast steel, turned cylindrically and bored conically; the lower edge of gouge is chamfered on the outer side to form a cutting edge on the inner circumference. The gouges are fixed at an angle to the revolving circular disc, and the chips escape through the centre of the gouges, which are widened at their upper end. When they become blunt or broken, they can readily be turned in their socket, thus presenting a fresh cutting edge.

In the year 1853 a Mr. William Hunter, of Glasgow, introduced a method of planing wood on the principle of the action of a circular saw; the planing tool consisted of a fine-toothed circular saw, having a 'dished' centre—that is, a slight concavity in the centre, similar to a very shallow plate or saucer. This saw was caused to revolve at a very high speed, and the wood was passed between it and a fence. The object in 'dishing' the saw was to allow only a narrow circumferential portion near the teeth to bear on the wood in cutting; the saw ran without 'set.' The inventor also claimed a modification whereby a single saw may be made to plane two contiguous sides of a piece of wood; the saw in this case was constructed with a double 'dish,' or a thick edge, with a centre sunk in or thinned off for clearance. We have never seen a saw of this construction in use for planing, so cannot speak as to its operation. Discs, with cutters projecting slightly beyond the surface of the disc, near the periphery, are now used for rough planing with more or less success, and we shall take an opportunity of noticing this method elsewhere. Some improvements in the feeding and general arrangement of details of roller-feed planing machines were patented by Nelson Barlow in 1855.

About the year 1856 Mr. Henry Wilson, then manager for Messrs. Powis, James, and Co., London, brought out a simple planing and moulding machine. For the feeding arrangement, in the place of all smooth rollers, he made the upper ones fluted, to increase the bite on the wood. The pressure on the wood was effected by means of a single weighted lever, with beams to distribute the pressure equally on the rollers.

Messrs. Robinson and Sons, of Rochdale, also about this time brought out a new moulding and planing machine, the chief novelty of which was that the spur wheels which drove the feed motion were actuated by a worm motion with four speeds. One of these machines, in which, however, were embodied other improvements, was exhibited in our International Exhibition in 1862. Messrs. Forrest and Barr, of Glasgow, also exhibited a planing and moulding machine. The feed consisted of a series of smooth friction rollers, geared together by long-toothed wheels. The upper friction rollers were adjusted by means of screws, and the pressure was applied to them by means of spiral springs.

Fig. 9 represents a heavy type combined planing and moulding machine from the designs of A. Ransome and Co., Limited.

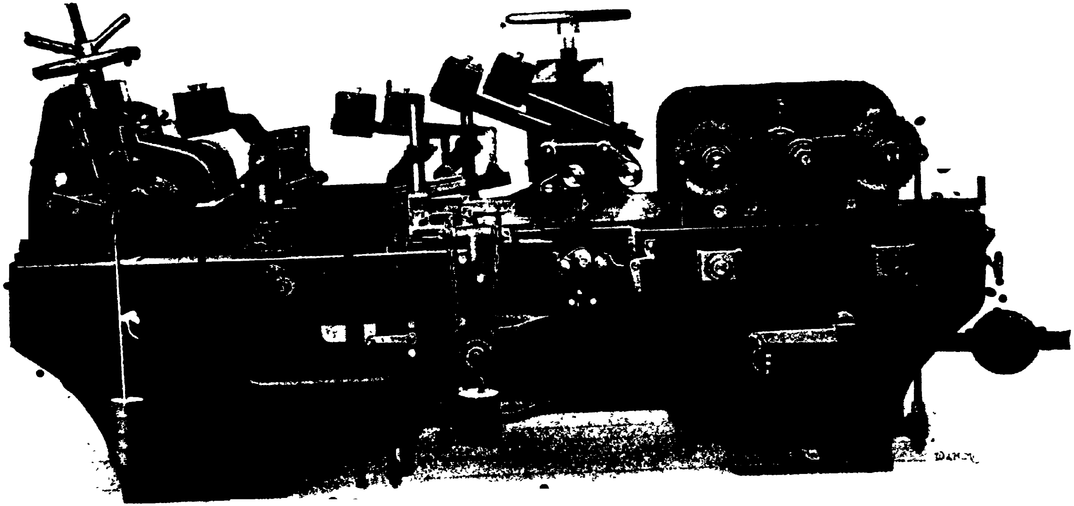

FIG. 9. COMBINED PLANING AND MOULDING MACHINE.

[To face page 94.

The main frame of the machine is of strong section, and cast in one piece to ensure freedom from vibration. The feed motion consists of four feed rollers, all of which are driven to avoid slip. Four different rates of feed—varying from 12 ft. to 50 ft. per minute—are provided. The feed roller gearing is placed at the back of the machine, thus rendering the cutters easy of access. All the feed gear has machine-cut teeth. The top rollers are raised or lowered simultaneously by means of worm gearing, and are fitted with wrought-iron plates on the fence side, the plates having their edges rounded and the fluting extended over the rounded edges, so as to grip the wood, when sawn on the bevel for mouldings.

The machine is fitted with top, bottom, and two side cutter blocks. The top cutter block is fitted with a canting arrangement, and the bottom block is mounted in an adjustable drawer, and its thickness of cut is regulated by means of an adjustable lip which can be locked in any desired position.

The pressure apparatus consists of a series of hinged rollers actuated by levers and adjustable weights, and are arranged to act on the wood close up to the cutter blocks to prevent its vibration when under the action of the cutters.

The same makers have recently introduced a special high-speed flooring and matchboard planing machine, which is arranged with variable speed gear to give feeds from 30 ft. to 240 ft. per minute, according to the quality of the wood. In this machine all the cutter blocks are fitted with six thin cutters of self-hardening steel, and a special jointing apparatus is also provided for them. The cutter-block spindles are arranged to run ball-journal bearings, fitted with dust-proof housings.

CHAPTER XI

PLANING AND MOULDING MACHINES—*continued.*

In the year 1864 Mr. Henry Wilson, of London, patented some very valuable improvements in connection with moulding and planing machines, the most important of which was a variable feed arrangement, which consisted of a disc wheel, from which, by toothed gear, the grooved rollers for advancing the wood to the cutters are driven; motion was imparted to this disc wheel by means of a clothed friction pulley, fitted on a shaft with a feather, along which the pulley was free to move, so as to act on the disc wheel at any desired distance from the centre. By regulating the position of the friction pulley, so will the feed be altered; the nearer the pulley is brought to the centre of the disc, the greater will be the speed of the feed. Included in this specification was an improved method of mounting the vertical or side-cutter spindles; these were fitted in movable frames, with curved slots, which are capable of being set by means of screws or otherwise, so as to allow one or both of the spindles to work at any required angle. This plan is found of great value when elaborate under-cut mouldings, hand railings, &c., have to be turned out.

In the International Exhibition held in Paris in 1867 an advanced type of planing machine was exhibited by Whitney in the American section; a machine also for further finishing the planed boards by means of scraping was also shown. This was done by forming a burr on a fixed plane-iron which projected slightly above the level of the table of the machine, and over which the wood was forced by means of geared rollers. This machine, improved by Richards, we illustrate (fig. 10).

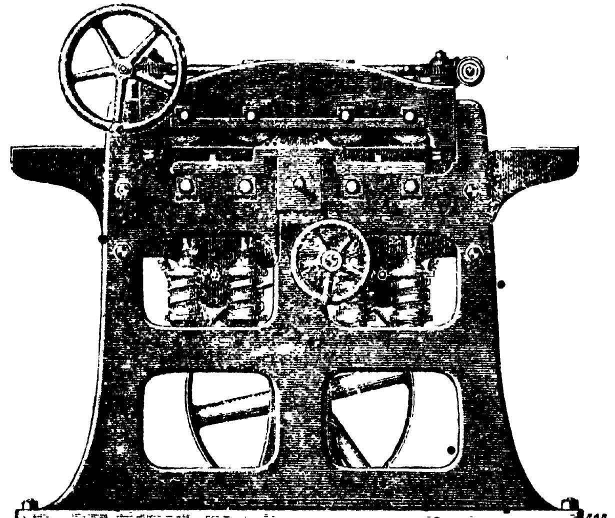

FIG. 10.—WHITNEY'S SURFACE-SCRAPING MACHINE.

In 1868 Mr. Samuel Worssam, jun., obtained a patent for improvements in planing machines, known as 'trying-up' and 'squaring-up' machines, whereby, in addition to their ordinary work, they were rendered capable, when desired, of simultaneously working on three sides of the timber under operation. This was secured by mounting in a suitable frame a pair of vertical spindles with cutters, with a pair of feed rollers. These spindles and feed rollers had a rotary motion given them, and were so arranged as to be easily moved out of the way when the edges of the timber, being worked, were not required to be operated on.

Messrs. Western and Co., London, have latterly made several improvements relating to planing machinery, for one of which they took out a patent in 1873. This invention related to apparatus for planing wood true on the face, and at the same time tonguing and grooving its edges, more particularly applicable in the preparation of parquet flooring. The table of the machine consists of an endless chain of plate links, caused to travel between two guides, and provided with edged 'dogs' for holding the pieces of wood, which are passed between revolving edge-cutters for grooving and tonguing, and under a planing disc, mounted on a vertical spindle, not over, but at the side of the wood. The wood, after being operated on, is released from the front 'dog' by the bend of the chain over the chain wheel, and from the back 'dog' by the withdrawal of the latter when it reaches a fixed stop. In the same year M. Bernard Clark, of Birmingham, took out a patent for some improvements in squaring-up and surfacing machines. These improvements consist chiefly of a series of small rotating discs or holders, which carry cutters for removing superfluous wood, and brushes or toothed cutters for producing a smooth surface on the wood operated upon, and are combined with a circular frame to which rotary motion is given. By the rotation of the frame and the discs or holders the tools are made to describe a series of nearly circular curves, which motion, combined with the rectilinear motion of the wood under the cutters or tools, is calculated to produce a truth and smoothness of surface unattainable by the ordinary surfacing machines. Modifications can be attached to a frame having either a rectilinear traverse motion or a vibratory or oscillating motion about a centre. The tools and wood to be operated upon may work in horizontal, vertical, or inclined planes.

In the recent International Exhibition at Paris several machines for planing and moulding were exhibited, some of which contained features of interest. A patent combined hand and power feed surface planing machine, exhibited by J. A. Fay and Co., of Cincinnati, U.S.A., is a valuable tool and well worthy of notice.

Fig. 11 represents a combined hand and roller-feed surface planing and thicknessing machine by J. Sagar and Co., Limited.

It practically combines two machines in one and is especially adapted for establishments where the business or space is limited. It can be adapted to a large range of work without change of cutters, viz:—Making glue joints, surfacing straight or taper work, bevelling, chamfering, cornering, rebating, squaring up, thicknessing panels, and boards, &c., and by the addition of suitable cutters it can be used for sticking beads, sash stuff, and mouldings, tonguing, grooving, &c.

The main frame is a cored casting made in one piece to absorb the vibration of working. The cutter-block spindle is forged from high carbon steel and revolves in heavy phosphor bronze self-oiling bearings. The cutter block is arranged to give a shearing cut, with straight cutters and has solid lips which act as back-irons and prevent tearing of the surface. The cutter-block spindle is ground after being turned.

The gearing for driving the feed rollers is machine cut from the solid and is arranged on one side of the machine so as to be out of the way of the operator. The top tables are adjustable on diagonal slides and are fitted with steel lips. The bottom table has anti-friction rollers, placed immediately under the gear-driven feed rollers.

Messrs. S. Worssam and Co., of London, exhibited a trying-up machine, in which the pressure rollers for holding the wood down on the travelling table, which are usually placed before and behind the cutter-block slide, are here both brought in front, thus securing a greater and more uniform pressure at the point where the cutter strikes the wood, which is an improvement. The cutter-block spindle ran in centres, but this plan can hardly be commended for the heavier class of machines. The travelling table is fitted with double rack gear, thus securing always an adequate bearing for the teeth of the driving pinion. A compact little thin-stuff surface-planing machine was shown by Messrs. Robinson and Son, of Rochdale; it was adapted to plane wood ⅛ inch thick at 60 feet run per minute, but the rate of feed could be varied according to the nature of the wood. The wood is fed by means of six plain rollers driven by toothed gearing, which force it over a fixed iron fitted into a movable drawer.

The roller-feed planing machine exhibited by Messrs. Gibson and Son, of Jonsered, in Sweden, although not possessing any great novelty in its general design and construction, attracted some attention. It appeared to be built more or less after American models.

The feed consisted of geared fluted rollers, adjusted by spiral springs and a distributing lever. The wood is first attacked by a revolving under-cutter, and then passes over a fixed knife fitted in a drawer and between two vertical side-cutters, and finally beneath the top cutter. This arrangement of the cutters is somewhat of an improvement, as a good bed is furnished for the bottom of the wood, and the edges are well dressed up before the final finish is put on the surface by the top cutter. The cutter blocks are made movable, and an additional cutter block is fitted for matching. The cutters are made in sections and fitted in mortise slots. The framing and general construction of the machine is very light as compared with English models.

In the Norse section Messrs. Jensen and Dahl showed a planing machine with spindle pulleys of extra large diameter, but with what object we are at a loss to see, as the friction to belts, &c., would thus be much increased. In the French section F. Arbey, of Paris, exhibited a trying-up machine, fitted with Mareschal and Godeau's patent spiral or twisted cutters. The advantage claimed for this form of knife is, that the pitch of the knives is so arranged that the end of one comes opposite to the beginning of the other, thus giving a continuous cut during the whole revolution of the cutter block. As part only of the whole length of the knives strikes the wood at the same time, the vibration is considerably lessened; and as they always present the same cutting angle to the wood, cross-grained and knotty stuff can be worked. The knives used are very light, being from one to two millimetres in thickness; they are, however, somewhat more difficult to manage than the straight knives; but an arrangement is fitted to this machine where, by means of a revolving emery wheel, they can be sharpened in their places on the block. The machine was fitted with a chain feed—a method which seems to be somewhat in favour for many kinds of machines in France—and the wood was secured on the travelling table by longitudinal 'dogs.'

A panel planing machine, with plain roller feed, to work 80 centimetres wide, was shown by Messrs. Gérard, of Paris. Instead of using two long planing irons, extending the whole width, eight short ones were arranged in succession, two on each side of the cutter block; this plan, although causing a little more trouble in adjusting, simplifies very much the operation of sharpening, as considerable difficulty is often experienced in keeping irons of very great width in satisfactory condition. Amongst recent improvements in planing machinery may be mentioned also those patented in 1878 by Mr. Richard Shill, of London. These improvements are more especially adapted for those machines arranged for planing blind laths and similar light work on all four sides at once, and the novelty consists in so arranging a series of fixed or hand plane cutters that the cutting action of the machine is not dependent on a high rate of speed, as is the case with revolving or rotary cutters, thus enabling the machine to be driven either by hand power or steam, as desired. The cutter for planing the under surface of the wood is fixed in an adjustable drawer, fitted in the table of the machine in the usual manner; the top cutter used for planing the upper surface of the wood, instead of revolving, as in most machines, is also stationary, and is fixed in a block or frame arranged in such a manner that it is capable of adjusting itself whilst in operation to the varying thicknesses of wood being planed. One of the cutters used for planing the edges of the wood is fixed in the guide or fence, whilst the other is made automatically adjustable to varying widths of wood by means of a spring. The wood is fed by means of pressure rollers in the usual manner, and the weight of the frame or block carrying the top cutter is also utilised in keeping the wood in contact with the bottom cutter whilst planing the under surface. If the machine is actuated by hand power, the inventor proposes to give the necessary rotary motion to the feed rollers by means of a handle or a fly wheel and belt. For the lightest class of work, especially where steam is not available, this machine should possess several features of utility. An illustration of it will be found (fig. 12).

Having thus briefly sketched the history of the invention and introduction of planing and moulding machinery in this country, we shall now proceed to discuss the chief features of this class of machines as at present in use. Although a larger number of machines are made, and specially arranged or modified to suit varying circumstances or descriptions of work, the principles involved in the cutting operation of planing and moulding machines are but three, and may be classed as follows:—First, and most important, those machines having their cutters fixed in revolving blocks or spindles; second, those machines having their cutters fixed in a rotating cross-head or disc (known as Bramah's principle); third, those machines having fixed irons only, and where the wood is forced over their cutting edge.

The principle of fixing cutters to revolving blocks or spindles is the one in most general use, and is, on the whole, the most advantageous for all ordinary classes of work, and will turn out a much larger quantity than any other system. In designing, in the first

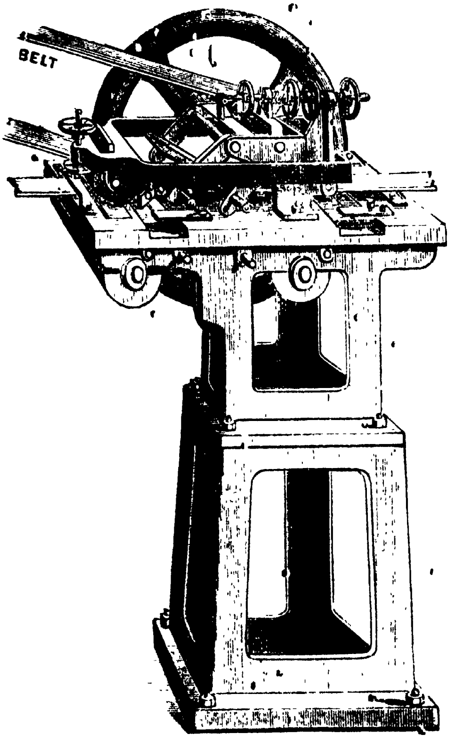

FIG. 12.—[illegible]'S PATENT THIN WOOD PLANING MACHINE.

place care should be taken to secure sufficient strength and stability in the main framing of the machine to overcome the strain and vibration caused by the high rate of speeds it is necessary to run at. For all the smaller-sized machines at least, the framing should be on the 'box' principle, and even in the largest sizes the framing should be in as few pieces as possible. To obtain compactness, however, the working parts should never be crowded together, as it often necessitates running intermediate driving belts at short centres, and other evils.

One of the most important elements necessary to secure the successful working of these, as well as other wood-working machines, is to obtain a reliable arrangement for feeding the timber through the machine, as, no matter how well designed or accurately made a machine may be, unless the timber passes through the machine steadily and without slip, and at a speed that is best suited to the class of wood being operated on, the quality and quantity of the work turned out are unsatisfactory. Chain and other methods of feeding were at one time in use, but the two arrangements now almost universally used are the roller and rack feeds. The latter, however, is confined to those classes of planing machines known as 'trying-up' and 'squaring-up' machines. Whether the rollers employed are plain on the surface or fluted, the grip on the wood and the feed is improved by driving the whole of them. Some makers drive only the upper series of rollers, leaving the lower to be made to revolve by the pressure of the wood being planed. In all large-sized planing or moulding machines the table of the machine should be a fixture, and the upper cutter-block arranged to rise and fall to suit varying thicknesses of wood.

We have seen a plan of placing all the cutter blocks on one side of the machine overhanging their bearings, and arranging the table to rise and fall. This may answer very well for small machines, where the strain is not great, but for large machines, owing to the heavy and unequal strain on the spindle bearings nearest the cutter blocks, it cannot be recommended, as when the bearings wear, the vibration and the consequent jar on the wood being planed are excessive, leaving its results in a series of undulations. The cutter-block spindles should be of steel, and not unduly heavy. A good plan to pursue is to forge the spindles and blocks revolving horizontally in one piece, and make the blocks on the side-cutter spindles movable. The cost of a tough steel for use in spindles is very little in excess of that of iron, and has the advantages of presenting a better surface to the bearings, and the spindles can be made of less weight.

In some machines of recent construction a duplicate set of top cutter-blocks and cutters have been introduced, with the object of allowing the first set of top cutters, under which the wood passes, to do the rough heavy work, and pass on to a second set of cutters, which are made to revolve at a much higher speed for the purpose of producing a fine surface or finish on the board.

The cutter-block spindle bearings should be of phosphor bronze, and made extra stout and long, and the oil ways should extend nearly the whole length of the bearings, and a constant supply of oil kept up. It is of the utmost importance that these spindles should be fitted to their bearings with the greatest accuracy, as the friction and vibration caused by the high rate of speed at which it is necessary they should run is excessive, sometimes engendering enough heat to cause the lubricating oil to take fire. When possible, these bearings should have guards or shields to protect them from dust and grit. All large-sized cutter blocks should have bearings at their either end, as it is found that when operating on heavy work the cutter-block spindles are apt to spring if they are supported by a single bearing only. Special care should also be taken in designing these machines, with the arrangement for holding down the wood being planed or moulded, as should it be allowed to vibrate even in a slight degree, the finished work is unsatisfactory.

The cutter blocks with their irons on either face should be made to accurately balance each other, or a waviness or irregularity in the finished work is the result. It is found a good plan to place the pressure apparatus for holding down the wood as near as possible to the cutter blocks, as it is thus enabled to make its controlling action felt to greater advantage than if placed a little distance from the point where the force is in operation which causes the vibration or 'spring' it is designed to counteract.

The cutter block operating on the under surface of the wood should be placed in advance of the block operating on the upper surface, as a smooth face is thus secured for the wood to travel on whilst passing beneath the upper or most important cutters. The countershafts should be placed at one end of the machine, to give a clear space to the workman. The cutting edge of planing and moulding irons should be speeded to travel about 6,000 feet per minute.

Of recent years great strides have been made in the larger planing machines and a series of some six or eight have been introduced by Messrs. Thomas Robinson and Son, Limited. A representative machine of this series is termed Type MS (fig. 13). It is an eight-roller planing machine designed particularly for large planing mills where excellence of finish—such as can only be attained by the use of fixed knives—is desirable.'

The bed consists of a feeding-in table, fitted with a flexible side pressure. After the feeding-in rolls and immediately before the bottom cutterhead, the bed is carried on an inclined slide for adjusting the thickness of cut, and is controlled from the feeding-in end by a hand-wheel and screw; the latter also causing the bottom feed rolls to rise and fall simultaneously. The depth of cut taken by the bottom head can be altered from zero to ¼ inch without stopping the feed.

The cutter spindles are all driven from the feeding-out end of the machine. The driving belts are wide, and run over heavy flanged pulleys, grooved to prevent slipping on heavy cuts or at fast feeds. The bearings are of bronze, self-oiling, and enclosed to prevent leakage and to exclude dust.

The bottom cutterhead can be adjusted vertically at either end. It can be quickly drawn out of the machine for sharpening and setting the cutters; it is not necessary to remove the driving belt, thus saving considerable time.

The side spindles revolve in long taper self-oiling bearings carried in rigid frames, supported on a massive cross slide, and are adjusted across the width of the machine by independent screws. The weight of the spindles is taken on heavy bronze footsteps, submerged in oil.

The top cutterhead frame is firmly held at either end by locking levers, and rests on planed slides, the bearings being connected by a massive cross-tie, carried below the bed, making the cutterblock exceptionally accessible.

The frame is raised and lowered by two screws, actuated from the side of the machine, the weight being taken on ball-thrust bearings. The cutter-spindle bearings are conical ring-oiling, each bearing being fitted with micrometer adjustment to take up any end movement.

The fixed knife-planing apparatus is arranged immediately after the bottom cutterhead, and consists of four independent knife boxes, which slide in a massive frame. The act of withdrawing any one of the knife boxes automatically pulls a planed filling-in piece into the position previously occupied by the knife box. To enable this to be done, each knife box has an independent series of pressure rollers fitted above it, a separate lever being used to operate each one. Any one of the knife boxes may therefore be withdrawn and replaced by a box with sharp knife without stopping the feed. There are also fixed knives for planing the sides of the timber after it passes the top cutterhead, one of which is mounted on a slide, and is quickly adjustable.

A rotary shavings breaker or chopper can be mounted on a slide carried in the main frames of the machine, the rotary chopper spindle being mounted in enclosed ring-oiling bearings. A suitable steel hopper is arranged to catch the long shavings from the fixed knives, and deflect them into the chopper, whence they can be conveniently piped to the pneumatic collector system if desired. To gain access to the shavings chopper, the hopper sides are raised by moving a lever, and the entire chopper drawn out on its slide to the front of the machine.

The pressures throughout the machine are designed to reduce the time taken in setting up, and to be self-adjusting as far as possible; and to hold timber that is twisted and which varies in thickness, firmly down to the bed before each cutterhead. Over the bottom head a double roller pressure is arranged on either side of the opening in the bed. The outer side head has a sectional steel face chip-breaker, which swings clear of the knives to allow of varying cuts. Large diameter roller pressures are provided for each side cutterhead, to hold the timber down to the bed whilst it is being matched. These pressures have independent flexible adjustment, and are raised and lowered by a handwheel at the side of the machine, to suit different thicknesses of timber. A heavy chip-breaker or radial pressure is attached to the frame carrying the top cutterhead bearings. This has adjustable sectional steel shoes, and is arranged to swing away from the knives as the depth of cut increases. An adjustment to suit different projections of the cutters is fitted. The pressure after this head is adjustable to or from the knives, as well as vertically, and, being attached to the top head, is raised and lowered with it.

The feed gear consists of eight feed rolls, four above and four below the timber, the upper set being carried in swings, and weighted from below. The first pair of bottom feed rolls are carried in bearings supported on adjustable wedges, which move simultaneously with the table in front of the bottom cutterblock for varying the thickness of the cut. The feed rolls are driven by machine-cut gearing, the first motion pinions being of steel. The lift of each set of rolls is independent.

The patent feed gear consists of expanding cones and a heavy V belt running between them, and although out of the operator's way at the end of the machine, is in full view and accessible. The rates of feed are instantly changed, when desired, whilst the machine is running.

Fig. 14 represents a high-speed four-cutter planing and moulding machine by John M'Dowall and Sons. The main frame is of solid construction and cast in one piece to secure freedom from vibration. The feed consists of four rollers of large diameter, all of which are driven by machine-cut gearing, and by means of the maker's patent gear box sixteen rates of feed may be obtained. It is claimed for this arrangement that the feed-belt speed is constant and all the feeds are positive and that it is superior to the various forms of friction feeds in use. The rates of feed may be varied at will from 25 feet to 100 feet per minute. The top cutter block is arranged to cant for cutting deep mouldings and the bottom cutter block is mounted in a drawing-out box which permits of the easy adjustment of cutters, and the amount of cut can be regulated whilst the machine is in motion. The pressure apparatus is by levers and weights which are readily adjustable, and all bearings are of the self-lubricating type.

Fig. 15 represents a four-cutter planing and moulding machine by W. B. Haigh, Gruban and Co., Limited. This machine is recommended for heavy as well as for light work. It is designed for exceptionally heavy feed gear, and has the following features:—

The bottom cutterhead is placed in front, thus giving a clean surface to the bottom face of the timber before passing the other cutterheads.

It is placed in a movable draw-out box, which gives instant access to the cutters.

The machine has three sets of feed rollers, the top rollers being driven by powerful machine-cut gear and chain.

The timber is fed through both horizontal cutterheads automatically.

The table is supported at each of the four corners by a strong slide.

The machine has three rates of feed up to 35 feet per minute.

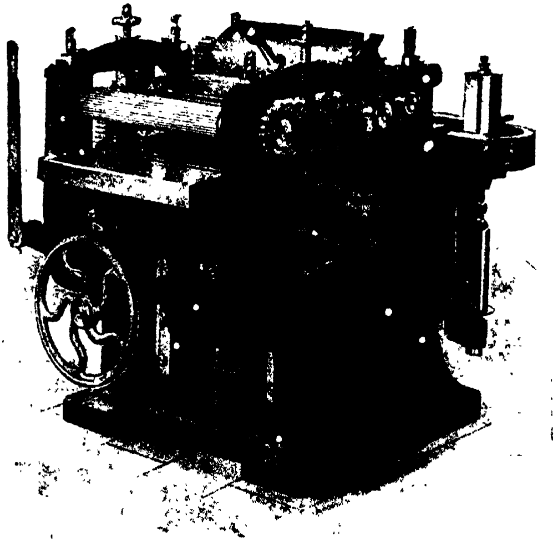

FIG. 35.—FOUR-CUTTER PLANING AND MOULDING MACHINE.

The bearings are of phosphor bronze throughout.

The horizontal bearings are of the self-lubricating ring type.

The machine is built to work timber from 12 inches by 6 inches in different sizes up to 30 inches by 6 inches.

The side spindles can be arranged to work with patent solid steel expanding cutterheads or Shimer cutterheads.

CHAPTER XII

IRREGULAR MOULDING AND SHAPING MACHINES.

MACHINES for moulding and shaping circular or irregular forms in wood are of comparatively recent introduction; they, however, effect great economy, as compared with hand labour, in the production of irregular ornamental work, as used in church architecture, &c. They are specially well adapted for working in hard woods, and will produce a large amount of work sufficiently perfect to require little or no finishing by hand. They can also be used to advantage for moulding ships' timbers, straight or circular cornice mouldings, table and side-board tops, chair and sofa frames, &c.; and when not in use for irregular work, they can be used for straight, such as sticking architrave mouldings, sash bars, stop-chamfering, grooving, rebating, thicknessing, &c. In fact, from the range and variety of its work, it must be considered a most valuable machine. A patent for shaping irregular forms was taken out in 1820 by one Boyd, but the method of moulding or shaping irregular forms in wood by means of a cutter block fixed on a spindle revolving vertically was invented and patented by Mr. Andrew Gear, of Janesville, Ohio, U.S.A., in the year 1853. The machine he then constructed is similar in every respect to those now in use. In the first machines made two steel spindles were employed, arranged to revolve in opposite directions; these were fitted in bearings lined with anti-friction metal and protruded through the top of a wooden table. The top of the spindles were screwed, and the cutters, of which there were two to each spindle, were kept in their places by collars and nuts. Both flat and curved cutters were employed; the shoulders of the cutter spindles and the under side of the collars were bevel-grooved, and the edge of the cutters made to correspond. They were thus held firmly in their places. A fence for sticking straight mouldings and a carriage fitted with chucks for 'pine-apple work' were added. For producing 'pine-apple work' the wood was made to revolve by turning the chucks first in one direction and then in another, and any degree of expanding pitch or twist on a screw-shaped table leg or other ornament was obtained by leaving the chucks free to revolve, and prolonging the extremity of one or both, the extremity being squared and twisted into the required shape and allowed to play endwise through an eye in the fixed standard. The inventor, it seems, made the discovery by accident, the first machine being constructed for one kind of work, and the extent of its range and easy adaptability to cut irregular and intricate mouldings was for some time undiscovered. Unlike many others, the inventor is said to have made large sums of money by the sale of his patents.

Storer and Bicknell, of Boston, U.S.A., patented some additional improvements in 1856. These consisted chiefly of an improved method of fastening the cutters and a self-acting method of setting the cutter spindles to angle for forming undercut mouldings. This was per-

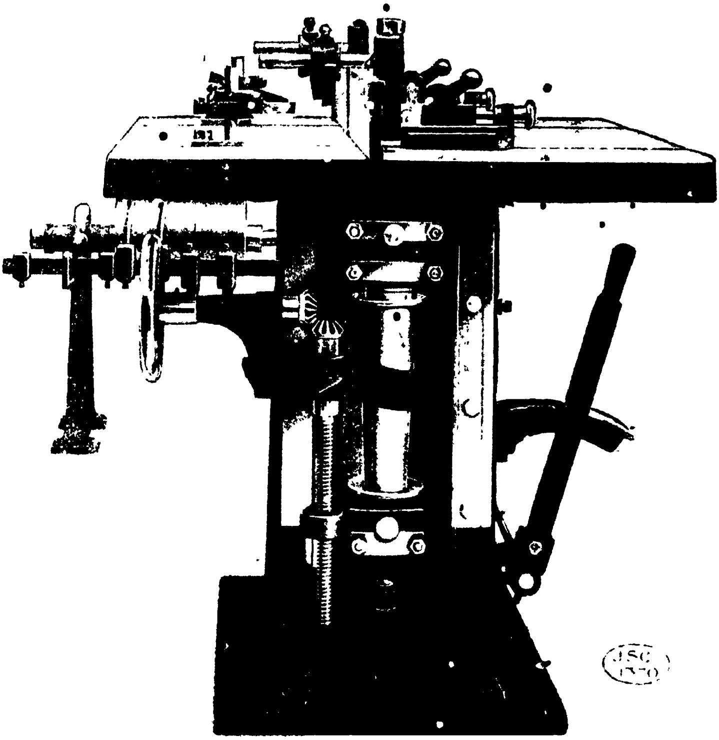

FIG. 16.—VERTICAL SPINDLE MOULDING MACHINE.

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formed by means of cone pulleys and worm and rack gearing working in a slotted quadrant.

Messrs. Greenwood and Batley, of Leeds, exhibited at the International Exhibition of 1862 a Kinder's patent shaping machine, which did not differ very essentially from those at present in use. It contained two vertical spindles, revolving in opposite directions. The cutter-heads or blocks were capable of separate vertical adjustment, and could be fitted with a variety of cutters, to suit the work being operated on. The frame of the table was fitted on trunnions, and made to cant either way. The top of the table was made to travel longitudinally, and was fitted with transverse grooves, which were used for fixing work. Since this date various modifications and improvements in these machines have been introduced by Messrs. Robinson and Smith, of Rochdale, Wilson, of London, and others.

Fig. 16 shows a vertical spindle moulding and shaping machine by J. Sagar and Co., Limited.

The frame of the machine is a cored casting made in one piece, and is fitted with a table with planed grooves across it to enable the fences &c., to be set square without loss of time. The slide carrying the spindle has planed ways the full length, and is adjustable vertically by hand wheel and screw. The bearings are of phosphor bronze, of extra length, turned on the outside and fitted into bored seatings. The cutter spindle and pulley are made from one steel forging to secure a true running balance. A loose head is fitted to the spindle, which is adapted to carry either a square cutter block, grooved collars, or solid reversible cutters.

The countershaft is arranged so that the cutter spindle can be readily reversed and run in either direction.

The method of driving and reversing single vertical shaping machines by means of frictional discs is, however, not new, but its mode of application may be. In some American machines the friction pulleys for driving and reversing are fitted to the countershaft. One friction pulley is fixed on a vertical shaft on which is the driving pulley, from which, horizontally, the driving strap passes through the back of the column of the machine, the pull of the strap thus coming against the whole body of the machine instead of against the vertical spindle and bearings only, as would be the case if the countershaft was put in the front of the machine. The friction pulleys for reversing, which are placed on the horizontal shaft, are brought into contact with the friction pulley on the vertical shaft by means of a treadle.

The tables of many of the American machines are made of cherry and black walnut wood glued together in strips and fastened with cross straps.

In the panelling and recessing machines, where the cutter spindle works from above, motion is usually given to it by friction pulleys placed inside the column, and the table brought up to the cutter by a treadle or hand wheel and screw.

In this country straight cutters are usually employed in irregular moulding and shaping machines, but on the Continent and in America curved or circular cutters turned from the solid are much used.

Shaping machines are usually constructed with one or more vertical spindles. Two spindles revolving in opposite directions is perhaps the most general and useful form, as by this plan one cutter spindle can cut with the grain of the wood running in one direction, and the other spindle can operate on the wood with the grain running in the other direction without stopping or reversing the machine.

The spindle, with suitable cutters attached, projects above the surface of an accurately planed table, and the cutting edges of the irons should be speeded to travel some 5,000 feet per minute. The wood to be shaped is fixed upon a wooden template, which is pressed by the operator against a collar on the cutter spindle; the cutters thus form in the wood the exact form of the template. In single-spindle machines, where the grain of the wood used is twisted and irregular, it is necessary to reverse the motion of the cutter spindle, so that in curved patterns the cutters may be enabled to work with the grain of the wood, or the worked turned out is rough and unsatisfactory. The cutter spindle should be of steel, revolving in extra long bearings of phosphor bronze, and capable of being raised and lowered to suit different classes of work by a lever and hand wheel or other suitable means. The top of the cutter spindle or head should be made movable, so as to allow of heads with other cutters fixed ready for work being put into operation without delay.

For straight work, such as sash bars, &c., a self-acting feed motion can be fitted; and for sticking undercut mouldings the table or spindle can be arranged to cant. We have recently seen an improved self-adjusting guard, fitted to this class of machines, to prevent accidents from the cutters. These guards cover the cutters entirely, but are raised sufficiently above the table to allow the wood being operated on to pass under them; they are fixed on turned upright pins, on which they can be made to rise or fall, to suit varying thicknesses of wood. These pins are fixed into turned rings, let in flush with the table, and, as the template comes in contact with them, they move and allow it to pass.

Various combinations of these machines are made, with overhanging cutter spindles, for recessing, moulding purposes, &c., but our space precludes more than a passing notice. The power required to drive is small.

CHAPTER XIII.

BAND AND FRET SAW MACHINES.

THE band-saw machine, although very generally believed to be of French origin, was really the invention of an Englishman. In the year 1808 a patent was taken out in this country by one William Newberry for a machine for sawing wood, in which an endless band or ribbon saw, strung over two wheels, was used. The inventor also claimed the use of it for splitting skins, &c.; in this case a plain steel or iron band, sharpened, but without teeth, was probably used. This invention, although very complete and original, lay dormant for many years, probably through the difficulty of obtaining blades of sufficient toughness to withstand the strain put on them, and the difficulty then found of re-joining the saws when broken. As will be seen from our illustrations (figs. 17, 18, 19, and 20), Newberry's machine possessed all the elements of practical utility, and although, from the inferior quality of the saws then obtainable, it failed to realise the inventor's anticipations, he is nevertheless entitled to the honour of being the originator of one of the most valuable of all wood-working machines.

It seems a band-saw machine was patented in France by M. Touroude in the year 1815, and again in 1845 by M. Thouard; but, owing to the constant breakages of the saws, they were only used on a very limited scale.

There is no record of many machines being constructed on Newberry's plan till 1855, when M. Périn, of Paris, exhibited at the French International Exhibition a much improved machine, on which he employed saws of French manufacture. From the mode of tempering these saws, they were enabled to stand the tension and strain necessarily put on them, and to run for a considerable period without breakage; thus the

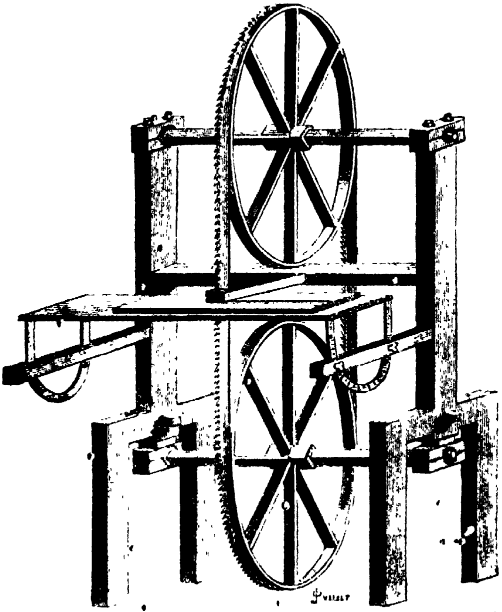


FIG. 17.—NEWBERRY'S BAND SAWING MACHINE, PATENTED 1808.

one great obstacle to the general use of these machines was removed, and after this date they came gradually into use.

Following M. Périn's re-introduction of the band saw, it was again patented in this country by M. Parienté, and once more by Exall and Barbour in the year 1856; so on the whole it must be held to have been well

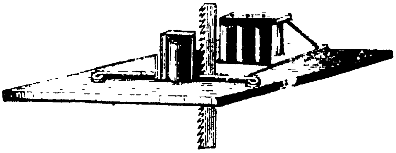


FIG. 18.

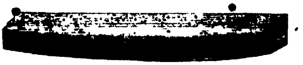


FIG. 19.

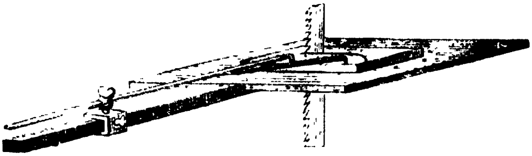


FIG. 20.

patented, but the invention of the principle undoubtedly belongs to Newberry.

The adoption was hardly general, however, till within the last few years, as, from the introduction of badly proportioned and badly constructed machines with inferior saw blades, a strong prejudice, on account of the loss arising from breakages, existed against them; this, however, is now entirely removed. Following the Paris International Exhibition of 1855, General Tulloch, late of the Carriage Department of the Royal Arsenal, at Woolwich, purchased a number of machines from M. Périn, and others of heavier construction were ordered; this example was soon followed by others. These machines, serving as examples to English engineers, led to heavier and more substantial designs being made, with other modifications and improvements, which rendered them more suitable to the heavy class of work carried on in this country.

Various patents for improvements of more or less value have been taken out.

In 1856 Samuel Worssam and John Grist obtained provisional protection for improvements in cutting and shaping wood for felloes for wheels and such like curved surfaces. They employed two band saws, set at certain distances apart, and mounted the blanks from which the articles were to be formed on a revolving platform, to which motion was communicated by other suitable gearing. The band saws were carried over pulleys, and worked in the same plane.

In the year 1858 Mr. Henry Wilson, of London, took out a patent for 'improvements in the mounting of band saws,' which he describes as follows:—

'My invention is intended to prevent the breaking or snapping of band saws from any sudden strain, or otherwise, while at work, and from the liability to snap on the cooling of the saws after ceasing to work; also to allow of ready adjustment of the bearings of the pulleys over which the saws are stretched. I connect to the bearing of the pulley over which the saw is stretched an upright rod or spindle, threaded at top, pass over the thread or upper part one arm of a lever, and adjust the spindle to the height required by a nut curved at bottom to fit any change of position in the lever, and to allow of the adjustment of the bearing of the pulley.

'The lever is centred upon a pin supported upon a pillar. The opposite arm of the lever is connected to a second vertical shaft, or rod, the lower end of which is connected to a vulcanised rubber or other spring, is carried down on the outside of the pillar, and is provided with a screw adjustment, or not, as deemed necessary. The bearing of the pulley before named being free to move up and down within certain limits, it follows that upon any strain upon or contraction of the saw, the spring will allow of the bearing yielding and thus prevent the snapping of the saw.

'I do not limit myself to the precise arrangement of compound lever with screw adjustment and spring compensation, or either, just described, although I believe it the best suited to the purpose of my invention; but I desire also to secure the so connecting of the movable bearing of a stretching pulley over which the band saws are stretched to a spring or springs, as will enable the saws to accommodate themselves to any sudden strain, and to contract without snapping.'

Mr. A. Kinder, of Westminster, in 1860 patented several improvements, consisting chiefly of a new form of packing box, through which the saw ran, either horizontally or vertically, and a variable feed arrangement for feeding the wood, consisting either of a reverse cone motion or a friction disc and pulley.

In our International Exhibition of 1862 several band sawing machines were exhibited, M. Périn showing one in operation which, from the dexterity of its operator and from the large amount of intricate and ornamental scroll-work it turned out, excited considerable attention. The pulleys carrying the saw were clothed with leather and Indiarubber, in lieu of the use of tension springs. A break for stopping the machine suddenly was also attached. Another French firm, Messrs. Varrall, Elwell, and Poulot, of Paris, exhibited a portable band sawing machine, with vertical engine and boiler combined. This machine was fitted with a feed arrangement, consisting of two pairs of rollers on vertical spindles, between which the wood passes. Only one pair of rollers was driven; these were fluted, adjustable according to thickness of cut. The other pair of rollers were plain, and were held horizontally against the wood by means of a weighted chain passing over a pulley.

M. Zimmermann, of Chemnitz, exhibited at our Exhibition of 1862 a band-saw machine, with an arrangement for circular cutting by swivelling the work horizontally on the table round a pivot fixed in it. Amongst the English manufacturers of band-saw machines perhaps the greatest novelty exhibited was a machine by Messrs. Greenwood and Batley, Leeds, especially constructed for cutting curvilinear shapes, as ribs for the frames of ships, and other heavy work of varying bevel, straight or curved. The table was stationary, and fixed in a horizontal position, to carry the work securely, and the saw frame was hung on a swivel, and could be set to any angle with the table. When ships' timbers or ribs are being cut for the bows of the vessel, they require to be cut to forms of double curvature, to suit the bilge of the vessel, from the keel upwards; and, in conjunction with that, they must be adapted to the tapering shape of the bow. The variations of curvature are marked in degrees upon the timbers at intervals along the curved line to be cut out on one face, the degrees expressing the successive angles of obliquity; and the saw being swivelled on a fulcrum, having its centre at or near the surface, is set, by the aid of a graduated scale, successively to the necessary angles. The laborious use of the adze was thus dispensed with. Instead of canting the saw table to obtain the necessary bevel in the wood cut, the main standard of the machine was mounted on trunnions, so constructed that the surface of the table was on a line with the centre of the trunnion. The main standard was also fitted with a variable and self-acting radial motion. Thus when the main standard was canted, the saw was permitted to oscillate freely, without changing its position with reference to the surface of the table. Arrangements were also made for fitting, if desired, a feed motion for carrying the wood through the saw. This motion could be driven from, and combined with, the radial motion, so as to produce in the wood any peculiar bevel required. Messrs. Powis, James, and Co. exhibited a band-saw machine fitted with Wilson's patent spring arrangement for preventing breakage to saws. The main frame of the machine was a hollow casting, and was the first example of the introduction of the hollow-casting system in connection with wood-working machinery. Messrs. Worssam also exhibited a compact and useful machine, but without any special feature of novelty.

In 1866 Mr. Henry Wilson, London, patented the combining in one machine a band saw and a jigger, or fret saw. Upon the brackets in which the spindle of each wheel round which the band saw works, or upon the spindles themselves, he attached an oscillating lever. One or both arms of each lever carried at their ends a quadrant or curved plate, and the upper and lower levers were connected to each other by a rod. The jigger saw was fastened in the ordinary manner between the quadrant of the upper and that of the lower lever, and as these levers were caused to oscillate the saw received an up-and-down motion, so as to act on the wood or other material being sawn. The oscillating motion was imparted to the levers by means of a link carried from the lower lever to an arm of a wheel placed at the back of the machine, or in any other convenient position.

Included in this specification is a modified spring arrangement for allowing the saws to expand or contract in working. This consisted in using a spring like a common carriage spring. This was supported on a bracket, carried up from the centre of the head of the main framing of the machine. One end of this spring was connected by a link to the side bracket carrying the upper saw wheel, and the other end was connected to the upper end of an ordinary tension rod, which was adjustable by means of a hand wheel and screw at the back of the machine.

In 1869 Mr. George Finnegan, of Dublin, patented an improved form of horizontal band sawing machine, which could, for a heavy class of work, be used in the place of the rack circular-saw bench or large timber frame. He claimed as novel, in connection with sawing machines, a method for converting a rotary motion into a reciprocating motion, or *vice versâ* and an arrangement for relieving the sides and backs of saw frames from undue friction. The machine consisted of an endless band saw, strung and revolving on two wrought-iron wheels of some 6 feet diameter, fixed at either side of a travelling table which supported the timber being operated on. The saw was arranged to cut horizontally, instead of vertically, as in most band-saw machines. The travelling table was driven by rack-and-pinion gear, and the rate of feed could be altered to suit the timber being sawn. It is claimed for this machine that it will cut a board from a hard-wood birch log, 6 feet long by 23 inches wide, in 60 seconds, and from a pine log 12 feet long by 14 inches wide, in 27 seconds.

CHAPTER XIV.

BAND AND FRET SAW MACHINES—*continued.*

IN 1873 a patent for improvements in band sawing machinery was taken out by Messrs. C. R. Western and J. Hamilton. These improvements may briefly be described as follows:—The pulleys carrying the band saw are fixed upon a bar, which is mounted at one end on a pivot in the axial line of the driving pulley, and at the other end is fitted to a box, in which it is free to swivel and to slide longitudinally. Both the pivot and the box are arranged to slide on parallel bars, and are each provided with gear by which they can be moved along these. According as the one or other is so moved, the saw is inclined more or less, so as to make a more or less oblique cut. The bar carrying the saw has two brackets, fitted with circular discs, having guide-slots for the saw blade, which discs can be turned so as to twist the saw blade more or less at each side of the timber. It will thus be seen that this machine, when used for bevel-cutting, combines the advantage of an ordinary machine with an improved method of canting the top saw pulley, instead of the table on which the wood to be cut is placed, thus securing a perfectly level surface, on which the wood can be moved with facility in any required direction.

Mr. Sansom, of London, in 1874 patented a band knife machine, specially adapted for cutting cloth and other materials. He drives an endless steel band in the ordinary manner over three wheels; but in the place of teeth the band is sharpened like a knife, and an arrangement is fitted to the machine for this purpose.

The chief novelty consisted in the peculiar means adopted for giving the required tension to the band knife, and to allow for its expansion and contraction.

The inventor makes the main frame of this machine to overhang considerably the table on which the work to be operated on is placed; this frame is lightly constructed, and, although made of cast iron, will 'give' or spring when the band knife is in operation, thus lessening the chance of breakage to saws or knives, which, in working these machines, is an item of great importance. By thus constructing the frame of the machine, considerable extra space is gained on the table for manipulating the cloth or other material being cut.

A patent was taken out in 1876 by W. B. Haigh, of Oldham, for improvements in band-saw machines, whereby he claimed that the power required to drive was considerably reduced. The plan he pursued was to place one of the wheels carrying the saw on a stud, at one end of a double lever, there being at the other end a spiral spring, the double lever working on a fulcrum or shaft running in bearings, placed in a slide fitted to guides, and having below the ordinary saw-tightening or regulating screw and nut; and thus, by placing the pulley on the arm of a lever, the tension can be so adjusted that much less power is required to drive the saw. In the same year M. Langlois, of

Paris, patented the plan of mounting band-saw wheels on pointed centres, with an improved grooved saw-guide, mounted on double points, to keep the saw to its

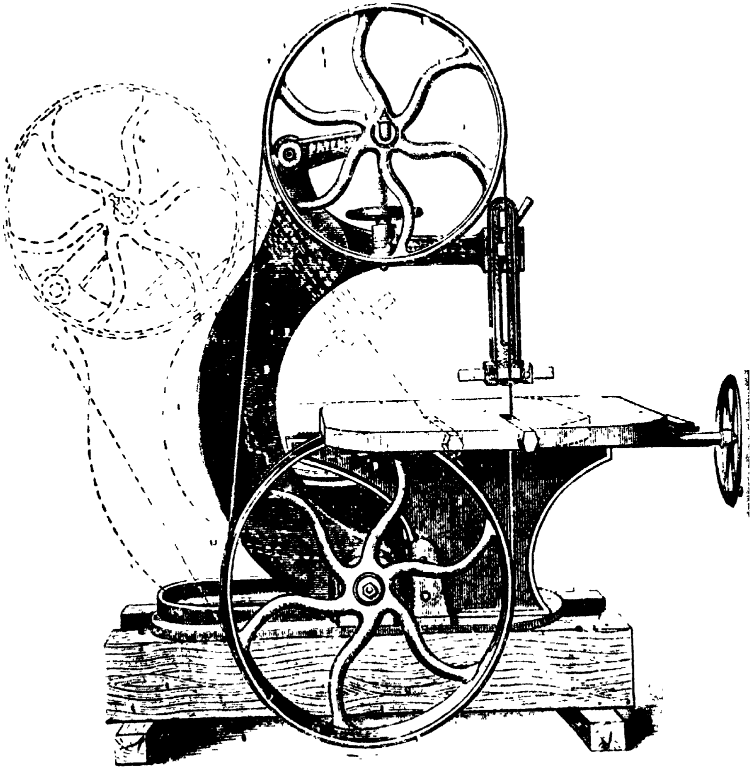


FIG. 21.—KNOWLING'S PATENT BAND SAWING MACHINE.

work. In the same year Mr. McDowall, of Johnstone, patented a multiple band sawing machine. He claims the combining of two or more endless band saws in one machine, so as to operate on the same piece of timber, making the standards of multiple band sawing machines adjustable, and mounting the pulleys on eccentric pins or studs, which can be adjusted for different thicknesses of cut.

Our illustration (fig. 21) represents a machine embodying several improvements which have recently been patented by Mr. Knowling, of Newton Abbott, Devon.

The chief points claimed as novel are:—In so constructing the machine that when the saw is canted for cutting at an angle, the table of the machine shall travel in a horizontal plane; undue strain on the saw is thus avoided, and the table carrying the wood is kept at a dead level. In most of the ordinary band sawing machines, when it is required to cut at an angle, the table carrying the wood is itself canted, and considerable difficulty is found in keeping heavy timber in position to be fed through the saw. The main frame of this machine is fitted at its base with trunnions, which work in the foundation plate. A screw is so arranged underneath the table, that, by means of the hand wheel shown in the engraving, the frame of the machine is canted, and the table moved at the same time. Another improvement consists in adjusting the tension of the saw by means of a pivoted arm or bracket, carrying the upper saw-wheel, which is acted on by a screw bedded on a spring support placed on a fixed rest. The patentee claims that the invention can be carried out in canting the saw by means of a screw, worm, or other mechanical contrivance, working on, or in, or against a movable metal frame carrying the pulleys actuating the band saw; the said movable frame being journalled at its lower end, on the same centre as the bottom saw pulley. The table is moved by the same motion actuating the moving frame, which for that purpose is connected with it. The tension adjustment can be performed by constructing the brackets of metal or other material, furnishing the brackets with a spring or sliding bed, on one end of which a screw works, the other end abutting against a pivoted arm or bracket, carrying the upper saw pulley, so that the turning of the screw separates the pulleys and tightens the saw. In Western's and other patents several of the points herein mentioned have before been carried out separately, but the combined movement of saw and table is novel, and must be mentioned as a decided advance in this class of machines, and should be found of service to cabinetmakers, chairmakers, and others requiring to cut much bevelled work.

In the International Exhibition of 1878 held in Paris, a large number of band-saw machines were shown, most of them in operation. Although this machine was chiefly developed by the French, they, of most other nations exhibiting, seem to have made less progress in rendering it efficient and complete in its every detail. We will briefly notice such machines as possess any special feature of improvement in their design or arrangement.

In the English section perhaps the most original form of band saw was that exhibited by Messrs. Western and Co., of London, one of whose patents in connection therewith we have just described. To allow for the expansion and contraction of the saw blades, a Wilson's patent spring arrangement was added; this we have also spoken of before. Messrs. Charles Powis and Co., of London, exhibited in their band-saw machine an improved method of canting the table for bevel-sawing; it consists of a modified form of the ball-and-socket joint arrangement.

Fig. 22 represents a 'new century' band resawing machine by W. B. Haigh, Grubb and Co., Limited.

This machine has been specially designed for cutting planks, deals, and battens up to the maximum capacity into thin boards.

The main frame is in one single heavy casting.

The bearings are of a new patent combination roller and ball thrust and recoil type, and are guaranteed to stand a strain of 100 per cent. over the working load without heating.

The top saw pulley with its shaft and bearings is mounted on a heavy bracket, with a bearing on each side of the pulley.

It is adjustable in height by lever and ratchet to give the necessary tension to the saw blade, and is fitted with canting arrangement and cross lining device.

A very sensitive knife-edge straining device with compound weighted lever is fitted to compensate for the expansion or contraction of the saw blade.

The bottom saw pulley acts as a fly wheel.

The feed gear consists of two fluted and two plain rollers driven by powerful machine-cut gearing.

An improved self centring device is fitted, to centre accurately boards from ¼ inch to 3 inches thick, by means of a foot lever.

The feed motion is by means of friction gear, instantly variable whilst the machine is in motion from practically nil to over 120 feet in No. 1 machine, and up to over 150 feet lineal per minute in No. 2 machine.

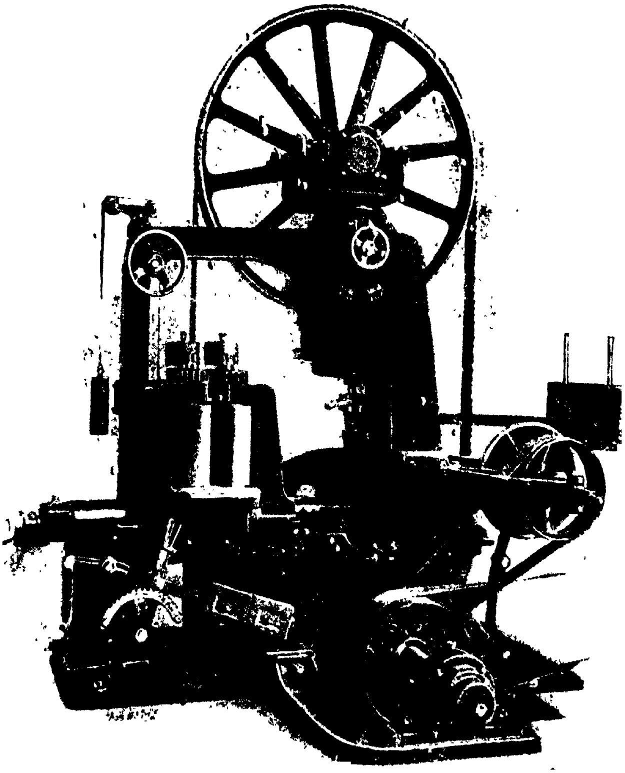


FIG. 22.—BAND RE-SAWING MACHINE.

The following are given by the makers as a few actual tests taken on the machine:—

Scots Fir—

2,000 lineal feet of 16 inches by 1 inch, split into 2 to ½ inch boards.	Or 3,576 superficial feet in one hour thirty-five minutes.
1,560 lineal feet of 7 inches by 2 inches split into 2 to 1 inch boards.	

Messrs. C. B. Rogers and Co., of Norwich, Connecticut, U.S.A., exhibited a band-saw machine carrying 36-inch wheels; the spindles are steel, and run in double bearings; these are fixed on an adjustable column fitted into the main framing of the machine, and rest on a thick indiarubber roller or washer, which gives to the saw when in work considerable elasticity, and allows for its expansion and contraction. The table is made of wood, glued together in strips, to prevent warping. A small rotating disc of steel receives the back thrust of the saw.

Messrs. Périn, Panhard, and Co., of Paris, to whom the development of the band saw is largely due, exhibited a number of machines, but they did not possess any special features of novelty; several of them are fitted with chain and other motions for feeding the wood for straight sawing. Another machine, running at a slow speed, and carrying a saw blade with fine teeth tempered as hard as possible, is used for cutting cold iron and steel.

Recently patented and fitted to a band-saw machine exhibited by M. Quétel-Trémois, of Paris, is an improved saw guide. It is constructed of gun-metal, and consists of three small square oil boxes, one placed on either side of the saw and one at the back. The side of each of these boxes nearest the saw is made movable and adjustable to the gauge of saw by set screws; these movable plates are made of steel or other metal, and a number of small holes are drilled through them, through which the oil percolates. In addition, at the back of the saw is placed a small revolving steel wheel, which receives the back thrust. Recording these small matters may to some appear trivial, but, owing to the keen competition of the day, anything, be it ever so small, that either saves labour or adds to the productive efficiency of a machine all practical men will admit is of importance. And here we may add that it is our opinion that much of the present success of American competition is due to the attention paid to the smallest details in their machine construction, which either increases the range of work performed, improves the quality, or lessens the cost of production, which saving in a day may be infinitesimal, but when multiplied by months or years amounts to a gigantic total. In point of fact, in comparing English and American machines for performing the same class of work, many American machines are carried *further* than our own.

M. J. Fau, of Bordeaux, exhibited a machine in which the saw wheels are constructed solid, of wood. By this plan he claims to drive with less power, as, being without arms, the wheel has less air resistance to overcome. Fixed directly to the bottom saw-wheel spindle and driving this machine was one of P. Martin's rotative engines, which made some 450 revolutions per minute.

M. Arbey, of Paris, shows a large number of machines, including a band saw for cutting heavy timber;

it is fitted with a self-acting travelling table for feeding the timber, and a lateral movement for bringing the timber up to the saw. The travelling table was also arranged with a hand-power chain reversing gear. We noticed on one of the lighter machines a compact little hand-rest for bevel-cutting.

CHAPTER XV.

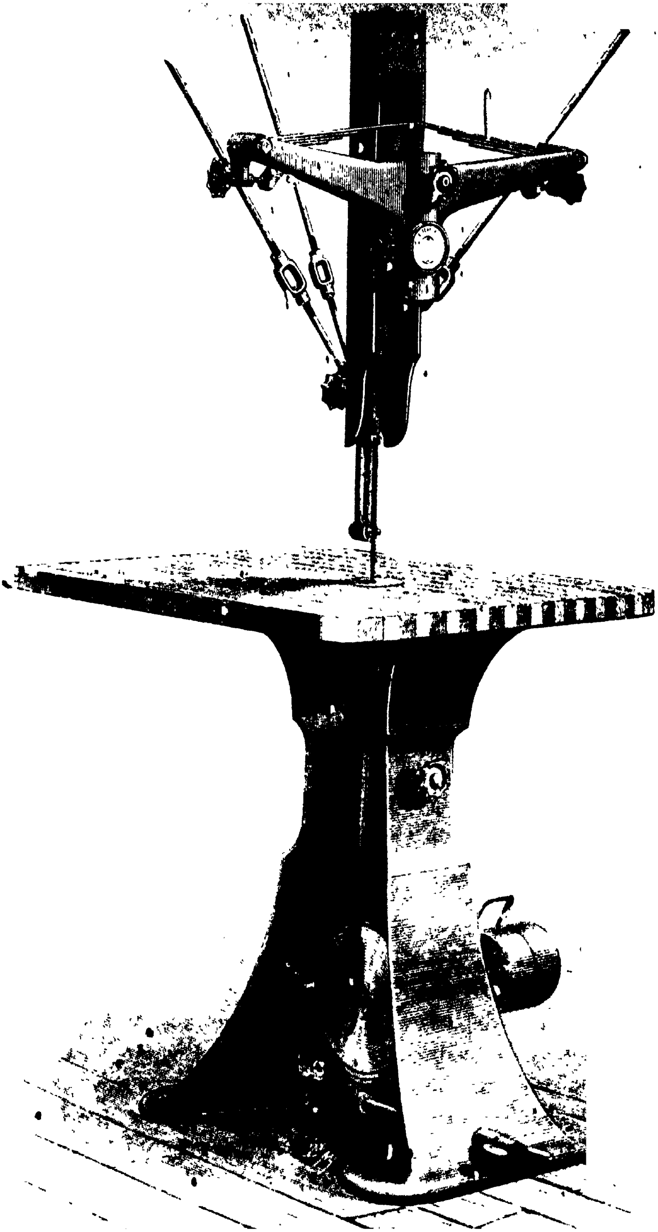
BAND AND FRET SAW MACHINES—*continued.*

The origin of the fret-cutting machine, which is also called the scroll or jigger saw, is obscure, but it was in general use long before the band saw, both in this country and America. For tracery, fret work, and other internal cutting, where the endless-band saw is not applicable, the fret saw is of considerable value. Hand-power fret cutting, by means of a bow saw, has been practised for a great number of years. Of late several improvements have been introduced, which render it more generally serviceable, amongst which may be mentioned a flexible self-adjusting bow saw, patented by a Mr. Cotter in 1872. In this bow-saw frame the stretcher is made of steam-bent beech wood, which forms a spring. The stretcher ends are jointed to the side bars; the top of the side bars are connected with the stretcher by two tension rods, fitted with thumb nuts at their outer ends; the other ends pass into female screws fitted in the stretcher. By turning these thumb nuts the tension of the saw blade can be varied at will. The end of each spindle for holding the saw has a longitudinal and transverse slot for receiving the blade and pin; slots to correspond are made in the sliding tube, so that when the tubes are drawn forward and turned the saw blade is firmly locked. The saw, by this plan, can easily be set or removed, and from the flexibility of the frame it is more pliable for cutting very sharp curves, and is also less liable to break from sudden strains put on it. Before the band saw was introduced, and after some years in a measure took the place of the fret saw, almost all kinds of irregular or curved sawing was performed by the fret saw; several other plans were, however, tried, but with little success.

From its novelty, a plan for curved sawing, invented and patented by E. B. Wells, of Uniontown, Pennsylvania, United States of America, in 1854, deserves notice. An angular incision was made in a circular saw, from the edge to the centre, or, in other words, a sector was cut from the disc, which was then sprung, by means of washers and rings, to any required degree of curvature. It was termed an adjustable, dished circular saw, and was designed for cutting barrel staves, wheel felloes, and such like work. It was intended to be run at a speed somewhat less than the ordinary circular saw.

Some fourteen years since, Mr. Talpey, of New York, made a fret-saw machine, worked by the foot, which embodied several improvements.

A very complete fret-saw machine is also made by Beach, of Montrose, United States of America. Motion is given to the saw by an adjustable friction pulley on the crank shaft, and the speed can be varied at will by the operator depressing a treadle. The saw guides are adjustable laterally and transversely to line, or to give any desired rake to the saw; the cross heads are also adjustable for wear. Tension is given to the saw by ratchet gear. The working parts are suspended to a



wrought-iron tubular shaft, which is held in place by a box and lever, and balanced by a spring. An adjustable steel bearing supports the back of the saw, and it can also be used to hold down the work. An air pump for removing the sawdust is attached to the cross head.

Mr. James Kennan, engineer, of Dublin, has from time to time introduced improvements into fret-saw machines. In 1865 he brought out a simple machine. In a vibrating or oscillating frame a fret saw was strained; the frame derived its motion direct from a triple-action cam, having two or more actuating surfaces on the first motion-shaft, which was worked by the foot. On the inner and outer peripheries of this cam, which was a flange screwed to the side arms of the fly wheel, worked two pulleys covered with india-rubber, to prevent noise when running. These pulleys were carried at the lower end of a lever, the upper end of which was keyed to a rocking shaft, which vibrated in bearings fitted to the table of the machine. Two arms of a C form were also keyed on to the rocking shaft, and the saw blade strained between their two vibrating ends. By making two or more acting surfaces on the cam, any number of strokes of the saw can be secured. An india-rubber ball or bellows, inflated by the upward stroke of the saw, was attached for blowing away the sawdust from the line of cut.

Mr. W. J. Cunningham, of London, patented about 1865 a combined fret saw and drilling machine, of very simple construction. The drill was vertical, and worked by leverage, and could be attached with advantage to an ordinary lathe. We have recently seen a well-arranged machine especially adapted for dovetail work, designed by a Mr. McChesney. The saw is driven by a cord passing over three sheaves, two of which are adjustable, and the tension of saw can be regulated thereby. The main frame is of C shape, and of light construction, but, to prevent oscillation, it is braced by means of a wire rope passed round its exterior. The table can be set to angle, to give the taper to the wood necessary in the curved form of dovetail it is designed to cut.

Messrs. J. A. Fay and Co., of Cincinnati, U.S.A., exhibited at the International Exhibition in Paris (1878) a very complete fret saw, which we illustrate herewith (fig. 23). As will be seen from the drawing, the body of the machine is cast in one piece. The reciprocating parts are made very light; the tension is flexible. The upper end of the saw is attached to a strap, which, at its upper end, is connected with a segment pulley and eccentric roller. To this eccentric roller is attached the straps, which are connected with two steel springs, made of a series of thin plates of different lengths. By this arrangement an almost equal tension throughout all parts of the stroke of the saw is secured. The eccentric roller is so adjusted that in the downward stroke of the saw the lessening flexibility of the steel springs is compensated for by the shortened leverage of the eccentric roller. The sliding cross-frame to which the springs are fitted is adjustable for different lengths of saws, and the small hand wheel in front of the machine sets the cross frame to any desired 'lead.' A patent combined brake and striking gear, worked by the foot, is attached, and is arranged to stop and start the saw gradually. The fast-and-loose pulleys are six inches in diameter, and are speeded to make 1,100 revolutions per minute.

Messrs. C. B. Rogers and Co., of Norwich, U.S.A., also exhibited a handy fret saw. The saw straining-frame consists of a light iron frame, adjustable to different lengths of saw, and has on either side a hard-wood spring, with adjustable tension, and is connected by straps to the saw. The saw is held by a hook and pin at each end, which allows it to be easily detached. The back of the saw is fitted with and steadied by a guide. We have seen another method of holding the fret saw introduced in machines made by J. Richards, of Philadelphia. In this machine the saw is not strained in the usual manner, but supported by steel anti-friction guides fixed at its top to prevent it turning and give lateral and back support at the same time. The saws are fastened to a tubular slide running in bearings, and steel guides are fitted to the end of the sliding tube. A small fan-blower is attached for clearing away the sawdust. A very good plan for keeping the cutting line clear in lieu of a fan-blower is, to construct a small cylinder with a piston which can be arranged to blow a volume of air at each downward stroke of the saw, and will perform its work very effectually. For light ornamental sawing a simple and compact machine, worked by the foot, has recently been patented by a Mr. Barnes, an American. The reciprocating motion is given to the saw by attaching the saw arms to a continuously revolving wheel. This wheel is driven by straps attached to the treadle, and the ordinary crank is done away with.

If, in designing a band sawing machine, it was practicable to embody some of the various improvements we have noticed without infringing patent rights, the result should be a comparatively perfect tool, combining that great desideratum in machinery the maximum amount of productive efficiency with the minimum amount of complication and loss from excessive wear and tear or breakage. As, however, this embodiment is unfortunately not practicable, we must content ourselves with a few general hints, which may be found of some service. The main framing should be rigid, and cast in one piece. For the lighter class of machines an ordinary flange casting is sufficient, but for the heavier type a hollow or box frame is to be preferred. Care should be taken that the frame is curved or bowed sufficiently to allow of ample room between it and the saw for the easy manipulation of the work. The saw wheels should be made as light as possible, and the upper wheel mounted in a slide, arranged to 'give' to the vibrations or any sudden impact of the saw. The saw-wheel spindles should be of steel, and run in double bearings of phosphor bronze. Sufficient care should be taken as to their lubrication. The periphery of the saw wheels should be covered with india-rubber or two thicknesses of leather, and turned inside and out, and accurately balanced. To lessen the breakage of the saws from expansion, contraction, or other causes, and to keep them at their proper tension, a weighted lever or spring should be fitted to the slide in which the top saw-wheel is mounted. Metallic friction guide-wheels should be provided to receive the back thrust of the saw, and adjustable wooden side-guides should also be added. On no account should the back of the saw be run against a fixed bearing.

In the heavier class of sawing it is found that, no matter how carefully it is operated, the saw is apt to buckle and run from the line; it is, therefore, necessary, in addition to the ordinary guides, to provide some plan to obviate this as far as possible; this can be accomplished by adding side friction rollers, placed on a spindle vertically, and arranged to guide from the teeth of the saw. The saw wheels should in all cases be made of as large diameter as convenient, as the friction, and consequent buckling and breakage of saws, is by this means lessened. For very heavy sawing blades three or four inches wide are used; the wheels should be of not less than 5 feet diameter; these are sometimes constructed of wood, or of iron centres and wooden rims. The upper saw-wheel should in all cases be so arranged that it can be set to an angle with the lower wheel, thus directing the saw to run on any part of the periphery, and equalising the wear on the india-rubber or leather covering. The table on which the work is placed should be arranged to set to an angle for bevel-sawing. A ball-and-socket movement is a convenient plan for this purpose; the angle can be determined by a gauge and pointer. For light bevel-sawing a small portable hand-rest should be provided, and for regular sweep-cutting, such as wheel felloes, chair backs, break blocks, &c., a radial arm is useful. The upper saw-wheel should be arranged to rise and fall to suit varying thicknesses of wood, as also the front saw guide-arm. It is now the practice in this country and America to construct the wheels carrying the saw without flanges; in lieu of this, at any rate in the larger machines, a small loose roller should be fitted to guide the saw blades on the upper wheel. These larger machines are sometimes fitted with a self-acting feed for straight sawing. A very good plan is to arrange vertically on the table two or more rollers, geared strongly together, and a fence adjustable by means of a hand wheel and screw to thickness of cut. These rollers are set in motion by suitable toothed or friction gearing, and the wood is fed between them and the fence plate. The feed rollers should be provided with changes in the rate of feed, to suit varying kinds of wood, and should be adjustable to and from the fence plate.

This self-acting feed is very useful where much panel or box work is required in addition to the ordinary curved sawing, for which a separate table should be used. In sawing the heaviest class of logs into boards by means of a band saw, which in the case of valuable woods is oftentimes done, in lieu of the feed motion above described, a travelling carriage, actuated by a rack, chain, or other suitable feed, is provided. Band saws are sometimes used for cutting iron, steel, copper, &c., when cold. In this case the saw is driven at a slow speed—some 250 feet per minute. The saw is tempered specially hard, and is made somewhat taper from the points of the teeth to the back of the blade. The iron to be sawn, is fixed in a suitable cramp or vice. Large band-saw machines are also constructed to work horizontally, for breaking down heavy logs. For this purpose the saw wheels are made of large diameter, and mounted on sliding brackets, working on two vertical columns; these brackets are raised and lowered simultaneously by a hand wheel and screw. The timber to be cut is carried underneath the saw, on an iron travelling table, fitted with rack or other feed, and a gauge and pointer are provided to measure thickness of the cut required. By certain modifications this form of horizontal band-saw can be adapted for cutting ships' timbers to the peculiar taper and bevel required in forming their keels. In New York band-saw blades are worked up 60 ft. long by 6 in. or 8 in. wide; but this large size are rarely, if ever, used in this country.

The advantages gained in using a well-constructed band sawing machine are many. In the first place, even in cutting heavy timber the power required to drive is small, and the cut is continuous. The wear and tear is small. As the dust falls through the kerf in sawing, the lines of the design can easily be followed by the operator. The saws can be used of very thin gauge, thus wasting little, which is a consideration when sawing valuable woods. Architectural designs, furniture work, &c., of elaborated design can readily be shaped out, thus effecting an immense saving over hand labour. In addition to cutting wood, band saws can be arranged to cut iron, bone, ivory, paper, cloth, leather, and other materials. In working band-saw machines care must be taken that the saw blades used are of the best possible quality, as, no matter how well a machine is constructed, if inferior blades are used the loss from breakages, stoppages, &c., will be considerable. Saws should not be used of greater width or gauge than is absolutely necessary. It is a mistake to suppose that saws of a thick gauge or great width stand better than thin ones. The reverse is the fact; they should be of exactly the same width and thickness throughout, and of uniform temper and set. The teeth of the saw should be set by blows on the inside of the blade, as in this case they are less liable to run off the wheel. They should be worked at a moderate tension The teeth of band saws for ordinary sawing should be speeded to travel about 4,000 feet per minute.

CHAPTER XVI.

STEAM MORTISING AND BORING MACHINES.

After the forest tree has been cut down, sawn, and planed true, the next operation is joining it together; the most general form of joint is that produced by the mortise and tenon. We shall in another place notice the operation of mortising as performed by hand-power machines; we now purpose taking the larger class of mortising machines worked by steam, and adapted to the heavier work required by railway-waggon builders, shipbuilders, contractors, and others.

Mortising machines may be briefly divided into two classes—those in which the chisel or cutter is worked with a reciprocating motion and those in which it is worked by a rotary motion. These two motions, however, admit of many modifications, to suit the different classes of work or material operated on. In this country and America machines with a reciprocating motion are most in favour, whilst France and other Continental nations generally prefer a rotary motion.

The invention of the mortising machine is generally attributed to Sir Samuel Bentham, in the year 1793. In 1807 Brunel, in connection with Henry Maudslay, made several machines for the Government, which were in successful operation at Portsmouth Dockyard and elsewhere for many years. These machines were chiefly used for mortising ships' blocks, which operation had hitherto been performed by manual labour. Rees, in his 'Cyclopædia' (1819), says, "The framing of all these machines is made of cast iron, and many of those parts which are exposed to violent and rapid motion are made of hardened steel, to avoid wearing; and where this is impracticable such parts are formed so that they can readily be renewed when worn out, the trifling repairs to cutting tools, &c., being made by the workman on the spot. These circumstances we particularly recommend to the attention of manufacturers who have occasion to employ extensive sets of machinery; for this, when well constructed, though expensive in the erection, is cheaper in the end than imperfect works, which require constant repair, the expense of which is the least evil, as it generally happens that a machine will fail at that time when it is most wanted, in consequence of being then most worked; and the loss occasioned by the stoppage of great works, particularly where many people are employed, is too evident to require our notice. In the same manner, an attention to neatness in the appearance of machinery has its advantages, by inducing the workmen to be careful of the machines they work at, to preserve them from the slightest injury, and to keep them clean from dust, which, trifling as it may appear, is a very essential part-preservation of those parts which are in rapid motion with friction against other parts, for dust getting between such surfaces grinds them away very fast and in their most essential points.' We commend the above paragraph to the attentive perusal of manufacturers and designers of any kind of machinery, as it conveys several wholesome lessons.

The mortising machines, designed by Brunel were arranged to cut the mortises in several blocks at one time. As many chisels as there were mortises to be cut were fitted to a vertical frame or slide, working between standards somewhat similar to the ordinary saw-frame. This vertical frame received a reciprocating motion from a crank and connecting rod. The blocks to be mortised were fixed on an iron travelling table, arranged to pass underneath the chisels; motion was communicated to the travelling table by means of a ratchet wheel and screw, so constructed that the table was moved forward the thickness of the chip it was intended to cut at each stroke of the chisels. The table also had a hand feed worked by toothed gearing, by which the operator could bring it up to the proper point for commencing the mortise. The chisels were provided with small teeth, which were fitted into dovetailed notches, formed in the blade of the chisel, and called scribers. They had a sharp edge projecting a small distance beyond the inside edge of the chisel, and therefore in descending through the mortise the scribers cut the sides of the mortise clear, and cut at the same time two clefts, which separate the chip which is to be cut out by the next stroke at its edges from the inside of the mortise, so that the chip comes out clear, without splitting at the edges, thus making the inside of the mortise as clear and smooth as possible. Each chisel had also a piece of steel fixed on it before the edge by a screw which projects from the middle of it, and is screwed into its blade, the upper end of the piece being received in a notch or groove formed in the chisel. This piece is for clearing the chips out of the mortise as fast as they are cut, for though in general these fall down the block, yet it may happen they will stick in, in which case, without this precaution, they would clog up the mortise with chips, so as to impede the proper action of the chisel. There were three machines of different sizes in operation, and the medium-sized machine was speeded to make as many as 400 strokes per minute, and the work turned out is reported to have been of first-class quality.

For some years no especial improvements on Brunel's mortising machinery seem to have been made in this country. Some thirty years ago Mr. Buck, an American, invented a machine with a somewhat ingenious action. The tool or chisel holder was arranged to slide between guides, and was actuated by a link similar to that used in the slide gear of a locomotive; this link was worked by a crank, or eccentric. The link was shifted by a treadle, so that when the block of the tool-holder is at the fulcrum end of the link the chisel is at a standstill, and the further the tool-holder block is from the fulcrum the longer is the stroke.

A mortising auger for making square holes, invented by Mr. A. Branch, of New York, was described in the 'Franklin Journal' of Philadelphia in the year 1826. It was stated to consist of an auger, formed, like the American screw auger, with the twisted part enclosed in a case or socket, extending from the upper part of the twists to the cutting edge, allowing the small entering screw to project beyond it. The external form of the socket is either square or otherwise, according to the intended shape of the hole to be bored, a large portion of its sides being cut away to allow the chips to escape. The lower end of the socket is steel, with a sharp cutting edge bevelled towards the inside.

The cutting edges are not allowed to terminate in right lines, but are made concave, so as to admit the angular points to enter the wood first, this causing it to cut with greater ease and more smoothly than it otherwise would. The upper part of the socket forms a collar, which works freely on the shank of the auger just above the twisted part, and is retained in its place by a pin and other appendages. When a longitudinal hole or mortise is wanted, two or more augers are placed side by side, furnished with their appropriate sockets, and retained in their places by various contrivances. This form of auger was invented about the same time in England by a Mr. Thomas Hancock, of London, and for some classes of mortising it is in use at the present day.

In 1853 Messrs. Slater and Tall brought out some novel machinery, especially adapted for cutting the wood work necessary in the manufacture of carpenters' planes. A mortising machine for forming the sloping sides of the cavity in the plane block necessary for the iron was very ingeniously devised, and may be briefly described. The cutting irons or chisels were bolted to two slides, facing each other, and working in dovetail grooves on the face of two inclined standards. The upper end of each of these slides was joined to a connecting rod, and the lower ends of both these rods to a crank pin, fitted to the face of a cast iron disc. This disc was keyed on to the end of a driving shaft, running in bearings, and fitted with fast-and-loose driving pulleys. The plane block to be mortised is held by screw clamps upon an inclined bed, set to an angle corresponding to the different inclinations of the sides of the cavity required in the plane block. When the machine is in motion the two cutters descend simultaneously and commence their cut close together, on the face of the plane block, and gradually widen as the block is set up, until the angular cavity is cut out the required depth. Another machine was designed for cutting the grooves in the cheeks of the plane's cavity. This machine was fitted with expanding cutters, which expanded gradually at each stroke, thus deepening the grooves in the block. When the proper depth of the groove was attained, the expanding mechanism was thrown out of gear. Each of the expanding cutters had three cutting edges; the outside edges widened the groove or slot in the plane block at each descent of the cutters, and the bottom edge cleared the wood away. The general arrangement and details of these machines reflect the highest credit on their designers, and may be studied with advantage by students and others.

About this date also (1853) Messrs. Bunten and Lamb, of Glasgow, made some machines for mortising and tenoning. In their machine the mortising tool was held in a spindle fitted in a small frame formed with slides, and working in vertical guides. A reciprocating motion was given to this frame by an eccentric movement overhead. The eccentric shaft was carried by a frame having a vertical traverse movement; and by means of a foot lever, which was connected to the frame by a rod, the mortising tool could be brought deeper into the wood, as required. The spindle carrying the mortising tool had upon it a pinion in gear with a short rack working in a slot across the frame; a pin carrying a friction pulley was fitted to the back of the rack, and projected through the slot. This friction pulley acted on a transverse sliding piece, by which the mortising tool was reversed when required, without stopping the machine.

Mr. H. B. Smith, of Lowell, Massachusetts, U.S.A., in the same year patented a plan for reversing mortising chisels by the foot. A grooved pulley was fitted to the chisel bar; round this pulley ran a gut band; this band was prevented from reversing the chisel by a stop piece; a motion of the foot, however, released the stop piece, and allowed the chisel bar to make just one half-turn, thus reversing the chisel without stopping the machine. A novel form of machine for mortising blind slats was also invented by Mr. Smith, who arranged the chisels to work by means of a series of cams on a revolving wheel. Two pieces of iron, of triangular section, were mounted in guides, and so arranged that together they formed a prism of some 2 inches square, each half having a separate movement. In the ends of these sliding pieces were mounted chisels, the bevelled sides towards each other; these chisels enclosed the mortise between them; and they could be made to any length or form desirable. The chisels were first driven singly, which marked out and sunk the mortise, and then simultaneously, which removed the core. The machine was arranged to set to any angle and to any distance desired between the slats, and to stop itself as each operation was completed.

Another American, Mr. B. H. Otis, of Syracuse, New York, about this time also introduced several improvements into mortising machines, including a method of varying the stroke of the chisel by a kind of link motion, which was derived from any point in a slotted lever. By means of a suitable bend in the shaft the link block may be placed exactly in a line with its axis, which position it assumes when released by the workman, and the chisel is immediately stopped. A novel device, applicable to treadle-made machines, for relieving the foot of the operator from the unpleasant jarring usually felt, was fitted to this machine. The treadle movement was transmitted through a triangular frame or wedge piece, the obliquity of which was about equal to its angle of friction, so that little of the usual jarring could be transmitted to the workman.

Prior to and following our Exhibition of 1851 considerable progress was made in mortising machinery in this country as well as in America. In 1849 Mr. W. R. Douglas, of Inveralmond, Mid-Calder, designed a machine for mortising, tenoning, boring, and ripping timber. The mortising was done by means of a fly wheel and double crank, connected to a cross head, to which the chisel was fixed. The wood was passed beneath the chisel between two guides, one fixed and the other movable, to suit different thicknesses.

To cut tenons, the mortising chisel was removed, and a frame containing two saws was fixed to the cross head. On the driving shaft was fixed an eccentric, which communicated motion to a ratchet wheel, which fed the wood beneath the saws. The ripping saw was driven by a large fly wheel.

In the year 1852 Thomas Guild, an American, introduced several very important improvements into reciprocating mortising machines, notably an arrangement for graduating the stroke of the chisel by means of a treadle, which set it in motion, and by the aid of a rod and links controlled its stroke. By another arrangement this machine was enabled to cut a mortise nearly equal in depth to the whole length of its stroke.

Although certain modifications have from time to time been introduced into it, it has substantially held its own to the present day as the most advanced machine of its class.

In 1853 Varrall patented a form of mortise chisel in which a small double-pointed tooth was centred in a recess, and arranged so as to project only as the chisel rose, thus drawing the chips out with it; this plan is, however, calculated easily to get out of order, and has never been much used. About this time also a chisel having serrated edges and a bird's-mouth point was patented by a Mr. Meyer.

In 1854 Mr. Adancourt, an American engineer, designed for use in mortising and boring machines a somewhat novel form of expanding boring bit, by means of which conical holes could be bored any desired depth, and the chips removed without boring right through the wood. In making it a bit or auger was formed in the usual manner, and then divided longitudinally into two unequal parts, the thicker section being formed with the entering centre of the bit, whilst the other was sprung outwards, as far as was necessary for the widest hole intended to be cut. An open collar was then fitted over the shank of the bit, so as to press the spring side section against the centre. The frame or collar-piece consisted of a pair of solid disc collars, connected by two inclined side arms, the propelling points of which extended down to the cutting points of the bit. When the bit was in operation, these points rested against the material being bored, and as the boring proceeded the collar frame was gradually pushed upwards, thus releasing the spring section of the bit and giving it an expanding width for the formation of a conical hole.

In our International Exhibition of 1862 a number of mortising machines were shown. Messrs. Greenwood and Batley, of Leeds, exhibited a well-designed machine, fitted with a graduated stroke, worked by a treadle arrangement. The chisel was reversed by a hand lever, and kept in position by a spring catch. The table carrying the wood had lateral and transverse movements, and was fitted with trunnions, which could be set to angle for bevel mortising.

Messrs. Robinson and Sons, of Rochdale, exhibited a machine fitted with a vertical and horizontal self-acting feed. The horizontal transverse feed was worked by a cam and ratchet motion. The vertical or descending feed was effected by means of a revolving screw, with a fixed bearing within the chisel bar, working through a nut in the stud, by which the chisel bar was driven. The screw was made to revolve by bevel gear from the crank shaft, and descending through the nut, carried the chisel bar with it, thus giving the descending feed.

The machines shown by the French engineers contrasted considerably with the English exhibits, being, without exception, constructed on the rotary principle. M. Périn, of Paris, exhibited a traversing mortising machine. The mortise was formed by a traversing rotary cutter, working from a horizontal spindle. The cutter used for deep mortises was a kind of double gouge, with cutting edges for penetration, and two longitudinal cutting edges for traversing. For shallow mortises a double cutter was used, fitted to a steel spindle. On this spindle two helical threads were cut, by which the chips were removed. The spindle was fitted in a movable traversing frame, which car-

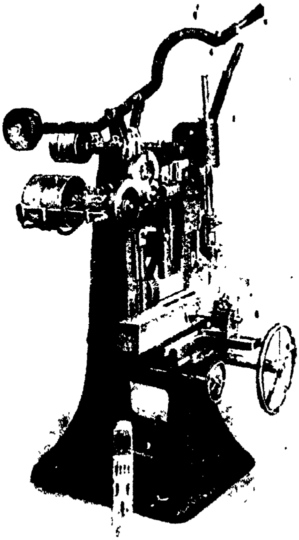


FIG. 24.—CHAIN AND HOLLOW CHISEL MORTISING MACHINE

ried also a cutter for squaring out the ends of the mortise.

MM. Bernier and Arbey, of Paris, showed a wooden-framed machine, in which the gouge or cutter, which worked horizontally, was of somewhat peculiar form. In appearance it was similar to an ordinary gouge, with a web at its extremity, subtending the arc like a segment of a circle; it was found to penetrate well, and readily cleaned itself. A double-ended square chisel, squared at both edges, with two inclined surfaces meeting at the middle, was used for squaring the ends of the mortises, which it did without reversing.

M. Zimmermann, of Chemnitz, exhibited a rotary mortising machine, the cutter of which was traversed by hand, but it possessed no special feature of novelty.

Following our Exhibition of 1862, improvements in mortising machinery were made by Barton, McDowall, Wilson, and others. In McDowall's machines a chisel with a serrated back is used, by which plan the saving of a considerable amount of time is claimed, and also that the core is withdrawn at every stroke of the chisel, and prevented from jamming itself into a compact mass, which oftentimes bends or breaks the tool, and causes considerable trouble in removal.

Fig. 24 represents a combined chain and hollow chisel mortising machine, by W. B. Haigh, Gruban and Co., Limited.

The main frame is of extra heavy design, and the machine is arranged with compound table, fitted with patent epicyclic gear.

The makers claim the following features in connection with their chain mortising machines:—

There is an entire absence of complicated mule or jockey pulley arrangements on account of the epicyclic drive, the pulleys remaining always in the same position.

The chain and hollow chisel can be worked quite independently of each other, and both levers are operated by the right hand.

The machine takes up less floor space than any other similar type machine.

The machine is fitted with an automatic fan which clears the chipping and enables the lines to be followed, and will take in timber up to 12 inches deep by 9 inches wide, and will cut mortises from $\frac{3}{8}$ inch by $\frac{1}{4}$ inch up to 3 inches by $1\frac{1}{4}$ inches wide, and $4\frac{1}{2}$ inches to 6 inches deep can be cut and finished at one stroke.

The hollow chisel and bit will make mortises from $\frac{1}{4}$ inch to 1 inch square.

Chain and hollow chisel mortising machines have been largely introduced of late years and have met with much success, the work being rapid and clean, and the power required to drive small.

The chain cutters are driven by a sprocket wheel, and run over a guide-bar which is fitted with an anti-friction roller at its lower end. The revolving cutters are brought down into the wood by a lever or treadle, and when correctly sharpened cut a clean mortise without splintering, no boring or core-cleaning being required.

It need hardly be said that the success of these machines very largely depends on the quality of the material and the accuracy of the work in the chain and cutters, and in the way they are sharpened and kept to their original cutting angle. In working these machines it is very important that the proper size and width of sprocket for the mortise to be cut is used, the chain should be amply lubricated, and never forced into the wood or bent sideways.

In the Paris International Exhibition, 1878, several mortising machines were exhibited, but none possessing any striking feature of novelty. Messrs. Robinson and Son, of Rochdale, showed a compact little combined rotary mortising and planing machine. The planing table was arranged to rise and fall, and the wood was passed over the cattling iron. For slot mortising the wood was brought rapidly up to the cutter by a quick-threaded screw.

We noticed one English firm of some standing exhibited a mortising machine with a positive stroke—that is, the chisel is driven to the bottom of the mortise at the first blow, a plan in every way objectionable, but this may be cited as an example of the conservatism that exists amongst some engineers even of the present day. Messrs. Gibson, of Jonsered, Sweden, exhibited a machine constructed after the American, or what is known as 'Guild's patent.' In this class of machine the chisel is stopped and started by a treadle movement.

CHAPTER XVII.

STEAM MORTISING AND BORING MACHINES—*continued.*

ALTHOUGH mortising machines may be classified under two heads, reciprocating and rotary, these motions are subjected to many modifications or arrangements adapted to different or special classes of work. It was the practice in this country for some years to construct reciprocating machines with a positive blow—that is, the chisel was allowed to plunge into the wood the full depth of the mortise at the first stroke, thus, in hard wood especially, causing an undue strain on the machine, breakage to chisels, and other evils. This plan has very generally been modified, or altogether abandoned. For door sashes and such like light work, perhaps the most simple and convenient form to construct a machine is so to arrange the chisel bar that it has a positive and continuous motion, and the wood that it can, by the foot or other means, be raised gradually up to receive the action of the chisel. By this plan the chisel is allowed to enter the wood by degrees, working deeper and deeper at each stroke, and the jar and concussion before spoken of are done away with. It also has the additional advantage of simplicity, and can safely be driven at a higher rate of speed. The table carrying the wood should be arranged to angle in either direction for bevel mortising, and to travel laterally under the chisel—a rack and pinion is a convenient motion. For light mortising the wood is often not clamped, but fed to the chisel by hand.

In some of the American mortising machines—which, on the whole, may be said to be in advance of ours—we have seen a novel form of compound treadle arranged to produce a varying throw of the table, as the change of work or depth of mortise may render necessary. An additional advantage in this treadle is that, though the machine may be run at a high speed, little vibration is felt by the operator. In a large number of the American machines the chisel bar is arranged with a graduated stroke. This motion is obtained by lengthening the connection from the eccentric to the chisel bar, starting from a still point above the extreme upper throw. This form, although possessing several advantages for the heavier classes of work, is considerably more complicated and less durable than the machine in which the crank shaft has a fixed position. In all machines a separate, vertical boring spindle should be provided, of sufficient range to reach the bottom of the deepest mortise. The centre of the boring bit should be exactly in a line with the centre of the chisel, so that after a clearance hole has been bored in the wood, it has only to be moved laterally to bring it directly under the chisel's action. In graduated-stroke machines the table carrying the wood, in addition to lateral and transverse adjustments, should be arranged to rise and fall to suit different thicknesses.

For mortising wheel stocks a separate slide must be provided, fitted with chucks or centres, to take the place of the ordinary table, and the stock is held between them. A dividing or index plate should be attached to one of the centres, and so arranged that any number of mortises can be cut in the stock without the necessity of marking out. The length of the mortises can be regulated by stops or otherwise. As a certain amount of angle, or 'dish,' is required in these mortises, the table carrying the centres must be arranged to cant.

Another form of machine, of American origin, but first made in this country some five-and-twenty years ago, is arranged with the chisel bar, crank shaft and its connections, fitted on a slide; and they are all brought down to the work by a connecting rod and counter-weighted treadle, thus enabling the chisel to enter the wood gradually. When the foot of the operator is removed from the counter-weighted treadle, the slide and chisel will rise from the work. This form of machine can only be recommended for the lighter class of mortising, as for the heaviest railway and other work the vibration is found to be excessive.

We have seen some well-arranged machines of this class made by Messrs. C. B. Rogers and Co., of Norwich, Conn., U.S.A., whose patent, we believe, it originally was. Their method of reversing the chisel deserves notice. When one end of a mortise is completed, the operator removes his foot from the counter-weighted treadle, the chisel slide rises, and the chisel is reversed by a worm on the chisel bar; it is then brought down again into action, and the mortise is completed.

In mortising machines for the heaviest class of work the boring spindle can with advantage, in addition to its ordinary boring operations, be arranged for slot mortising. This can be secured by mounting the spindle in a bracket sliding transversely on the face of the main column of the machine, and motion can be imparted to this bracket by an adjustable crank driven from a countershaft.

Machines are sometimes constructed where the stroke of the chisel is governed by a variable eccentric, which increases or diminishes the throw in either direction; but, except for very special purposes, these, owing to the increased vibration and consequent wear, cannot be recommended.

Having discussed briefly the various forms of mortising machines with a reciprocating motion, which, by the way, must be considered by far the most important class, we conclude our notice with a few remarks on rotary machines. The principle of cutting mortises with a rotary bit or cutter (invented and described by Bentham, 1793) has the great advantage of simplicity, but has the disadvantage of leaving the ends of the mortise round and not square, as in the reciprocating machines; but when used for chair-maker's work, posts, &c., where a round-headed mortise is no detriment, it has many advantages. Amongst others it can easily be applied and worked in conjunction with saw benches, tenoning, and other machines possessing horizontal spindles running at a sufficiently high rate of speed. For chair or other work where a large number of duplicate pieces are required, it is much more expeditious than a machine with a reciprocating motion, and can readily be applied to either curved or straight work. In saw benches and machines with spindles in a fixed position the wood is usually cramped on a slide, which receives a transverse motion from a hand lever. It is fed forward to the mortising auger by a hand wheel and screw, or other suitable means. This slide or table is made to rise and fall, and is fitted with adjustable stops, which accurately gauge the length and depth of the mortise. This arrangement is found very serviceable for many kinds of rough mortising, such as posts for fencing, hurdles, &c.

Rotary or, as they are sometimes called, slot mortising machines are often used for mortising the heavier class of railway-waggon and other work. The wood is usually cramped firmly on a travelling carriage or bed with a self-acting motion. The spindle carrying the mortising auger is mounted in a slide having vertical and transverse movements, and is brought to the work by a lever. The depth of the mortise is regulated by stops on the slide frame, and the length by stops on the travelling carriage.

Some years back a Mr. Lemmans, an American, designed and patented a very complete rotary mortising and boring machine, especially adapted for chair work, either straight or curved. One end of the spindle carrying the mortising auger moved in a ball-and-socket joint, which allowed the spindle to revolve, and the vibrating end to be moved in any desired direction. By means of a curved bar upon which the movable end of the boring spindle slides, either curved or straight mortises could be produced. When the curved bar is placed horizontally, the mortises are straight, but when inclined to the perpendicular they are curved. An adjustable crank and connecting rod served to regulate the traverse of the mortising auger. The table on which the wood is cramped is moved by a lever and rack and pinion, by which the depth of the mortise can be regulated; and the table is also raised or lowered by a hand wheel and screw, to suit the different positions of the mortises. When a number of small mortises in hard wood are required, mortising machines on the rotary principle should be adopted, as being more expeditious and easier of management than the reciprocating machines, as in these considerable inconvenience is caused from the bending of narrow chisels, the difficulty of removing the core in deep mortises, &c.

A convenient form of machine for this class of work is one in which the revolving auger is made to have a traversing movement, by means of an adjustable crank, the wood being stationary. By this plan no difficulty is found in removing the core even from the deepest mortises. Arrangements should be added to vary the speed of the mortising auger, according to the nature or quality of the wood being operated on.

For boring and mortising blind stiles, &c., Messrs. J. A. Fay and Co., of Cincinnati, United States of America, have introduced an ingenious machine. The stiles are mortised or bored in pairs. The boring spindles are worked by means of a cam, which, after each operation is completed, returns to its original position, ready for the next pair of stiles. The depth of the mortises is regulated by a vertical adjustment of the spindles, and the distances between the mortises by a rack to which the spindles are attached. They can be cut at an angle, if desired. The stiles are held firmly whilst being worked, but are released and fed forward as required by a self-acting feed, which cramps them again as before. In France the great majority of the mortising machines are on the rotary principle; a simple hollow bit is used, and the round ends of the mortise are afterwards squared by a double-faced chisel. Machines adapted for boring only are constructed in endless variety, according to the nature and quantity of the work to be performed.

The operation of boring holes in wood by mechanical means is doubtless very ancient, but when the first combination that may be dignified by the name of 'machine' was first constructed we have no record to show. Sir Samuel Bentham's oft-quoted patent specification (1793) contains a long description of tools and appliances for boring wood, including most of the ordinary boring tools now used. Before the introduction of iron pipes for carrying water, wooden pipes were used, and these, it seems, were bored by machinery. Belidor speaks of a machine for this purpose, where the tree to be bored was securely fixed on a travelling carriage. A vertical shaft, put in motion by a water wheel, is made to give rotary motion to a horizontal shaft, carrying at its extremity an auger. Motion was also given to a drag wheel, the rope on which was attached to the travelling carriage bearing the tree, so that as the borer cut its way the travelling carriage was gradually drawn towards its work till the hole was cut through. The carriage was now run back, and a larger auger introduced, till the hole attained the requisite diameter. By another plan the tree was made to revolve.

A Mr. Murdock, in 1810, took out a patent for an improved machine for forming wooden or stone pipes. For boring wood he employed a hollow cylinder, fitted at its extremity with a circular trepanning saw. The tree was placed vertically above the cylinder to admit of the dust falling out of the saw kerf as the operation proceeded. The boring cylinder was given a rotary motion by means of rope gear worked by manual labour, and as the saw cut its way the core entered the hollow of the cylinder whole, thus wasting little material.

The general form of machine at present in use is too well known to need much description. For special purposes, such as boring dowel holes in chair frames, or where a large quantity of similar work has to be performed, especial means must be adopted. For chair work the writer can confidently recommend the following plan:—In a circular frame or pulley mount horizontally two or more boring spindles, in arms swinging radially from a centre spindle. These arms must be capable of being moved round, and fixed to any part of the circumference of the circular frame, according to the distance apart it is desired to bore the holes. A sliding table, with vertical and transverse movements, should be fitted horizontally beneath the boring bits, to carry the wood. Stops to regulate the depths of the holes can be fitted to the table, and the whole, with fast and loose pulleys and countershaft, can be mounted on a suitable column. Should it be required to bore the holes at an upward or downward angle, the table can be fitted with a radial adjustment. For general purposes what is known as the American screw auger is the most expeditious and reliable form of boring bit to use.

In designing mortising and boring machines with a reciprocating movement it is important that the main column should be of sufficient strength to overcome the continuous vibration of the chisel. The hollow or 'cored' pattern column, with an extended base, is undoubtedly the most satisfactory form. We need hardly add that the workmanship must necessarily be of the very best, this applying more especially to the machines constructed with a graduated stroke, whose reciprocating parts should combine, in the greatest possible degree, lightness and strength. In the graduating movement each part should be bored, turned, and compensated, or this form of machine will be found to deteriorate rapidly.

CHAPTER XVIII.

TENONING MACHINES.

MORTISING and tenoning are so inseparably connected, as being together in fact the principal joint used in wood-working, that, following mortising, we naturally discuss tenoning machines. The invention of a system or machine for cutting tenons otherwise than by hand labour is generally attributed, and we believe correctly, to Sir Samuel Bentham, in 1793; at any rate, there is no doubt that he was the inventor of the principle of rotary cutters for working wood, and that about this time machines for forming tenons were made and supplied to the Government of this country. There is not, however, as far as we are aware, any record of the system pursued, or whether the tenons were formed with saws or cutters. Tenons were formerly cut by hand, with what is known as a tenon saw; a plan of cutting them with an arrangement of reciprocating chisels seems to have been tried also, and abandoned, as slow and uncertain. The machines at present in use may be divided into three classes, as follows:—(1) Machines which form the tenons with cutters running parallel or vertical, and working across or with the grain of the wood. (2) Machines which form the tenons by an arrangement of saws. (3) Machines in-which the wood to be tenoned is held vertically, and passed between circular cutter discs or saws. These three principles are, however, often combined or modified, to suit special requirements.

Class No. 1, with cutters working parallel and across the grain of the wood, is the most simple and generally adopted system for all ordinary classes of work. In these machines two or more cutter-block spindles, revolving at a high speed, are mounted in sliding brackets, having vertical screw adjustments, which can be worked either independently or simultaneously, upon the face of an upright column. Sometimes the upper cutter-block spindle is furnished with a lateral movement in addition, to enable it to cut one shoulder of a tenon longer than the other, if wished. The wood to be tenoned is cramped on a travelling table having a transverse movement, but working parallel to the centre of rotation of the cutter blocks. This travelling table is usually mounted on friction pulleys, running in V-shaped guides, and, except in the heaviest machines, which are fitted with a self-acting motion, is traversed to and fro by hand. The adze irons or cutters are flat, and are arranged at an angle on the blocks which gives a kind of shearing cut; segments of saws or lancets are fitted at right angles to the block, for cutting the shoulders of the tenon. For cutting double tenons a vertical spindle, fitted with a 'drunken' saw or cutter disc, is provided for scribing the shoulders, in lieu of the saw, a suitable cutter disc or block is substituted. The cutter-block spindles are driven by an 'in-and-out' belt, which passes over an idle tightening pulley, which can be adjusted to any required degree of tension by means of a pulley and weighted rope or hand wheel and screw, thus securing a constant and uniform grip of the belt.

For the heaviest class of work, such as is used in the construction of railway waggons, &c., which is sometimes too heavy to be traversed readily past the cutter blocks, a plan often pursued is to mount on a vertical spindle three movable cutter blocks, which can be adjusted to cut single or double tenons of any size. This cutter spindle is mounted on a travelling carriage, and is made to traverse past the end of the timber to be tenoned, which is carried on a suitable table, attached to the main frame of the machine. The timber, when under the action of the cutters, is cramped tightly against a fence, which is arranged to cant for cutting diagonal tenons.

After hand labour the first mechanical method adopted in forming tenons was by an arrangement of circular saws, working at right angles to one another (Class 2), those running parallel to the grain of the wood cutting the sides, and those at right angles the shoulders, of the tenon. The two saws cutting the sides of the tenon are of the same diameter and mounted on the same spindle, a collar being placed between them to regulate the thickness of the tenon; the saws forming the shoulders are mounted on separate spindles, running at right angles to the above. This method of cutting tenons has, however, almost entirely given way in favour of the rotary-cutter system, which produces a higher class of work at a greater speed, and is much easier of adjustment for special purposes. For cutting simple tenons on a rising spindle saw-bench it is, however, of value, and some French engineers even now construct machines on this system; but for what reason this conservatism exists we are at a loss to see. For cutting round or oval tenons, such as are used for the spokes of wheels, blind slats, &c., the plan adopted in America is to carry the cutter head round the piece to be tenoned, or to make it rotate against a revolving cutter-block. Tenoning machines, working with rotary cutters, similar to those now in use, were first made in America—at any rate, in any numbers—by the late Mr. J. A. Fay—originator of the well-known firm of that name now trading at Cincinnati, U.S.A.—in the year 1840, or thereabouts. The framings of these machines were of wood; they were well designed and constructed, had most of the adjustments as now in use, and are reported to have turned out a large amount of excellent work; in fact, it may be said that of all the wood-working machines these, since their first introduction, have received less alteration in their general design and functions than any other. Of course various minor modifications and improvements have been introduced from time to time, as experience or necessity has dictated; but the inventor or designer of a machine for so important an operation in wood-working as tenoning, that has stood the test of a long series of years without any important alteration, must have been a man of no mean talent, especially when we consider the many thousands of machines that have during these years been constructed on this principle.

One of these wooden-framed machines was shown in London, at our International Exhibition of 1851; it was copied by several English firms, and has been manufactured extensively ever since.

In our International Exhibition of 1862 several tenoning machines were exhibited, but none possessing any special feature of novelty. A heavy tenoning machine shown by Powis, James, and Co., London, was fitted with a self-acting table, which, after the tenon was formed, was, by means of a clutch coupling, reversed at double speed. In the machine exhibited by Robinson and Son, of Rochdale, the cutters were twisted obliquely, and so screwed to the block.

MM. Bernier and Arbey, Paris, showed a machine in which the cutters revolved at right angles to the wood, and with the grain—the reverse of the general English method, which works across the grain.

About the year 1866 Powis, James, and Co., of London, introduced an improved tenoning and cross-cutting machine, especially adapted for cutting single or double tenons on the diagonals, sides, and bearers of railway waggons, and similar work. The table carrying the timber had a self-acting traverse motion, and was constructed to carry four waggon sole-plates at once. It was also arranged with a circular swivelling motion, so that when the one end of the timber had passed through the cutters, the table was swivelled round, and the other end subjected to the same operation on its return motion. A circular cross-cutting saw was mounted on a slide, fitted to a separate column on the bed plate of the machine. This saw was arranged to cross-cut the pieces of timber being tenoned, thus bringing them all to one uniform length.

A few years since C. B. Rogers and Co., of Norwich, U.S.A., patented some improvements in tenoning machines, consisting chiefly of a novel form of adjusting screws for regulating the cutter blocks and the thickness of the tenon. This screw is made hollow, and worked through a lock nut at the top of the main column; it is attached to the top cutter-block sliding brackets, and is operated by a hand wheel. Inside the hollow screw is fitted another small screw, which is worked by a crank handle above the hand wheel before spoken of; this smaller screw passes through a lock nut in the bottom cutter-block bracket. By moving the crank handle the lower cutter block is moved, and the space between the blocks is adjusted to suit the thickness of tenon; the bottom lock-nut now fastens it in position. By moving the hand wheel and hollow screw, both cutter blocks are moved at once, and can be adjusted to any desired height above the table carrying the wood; they are then fixed firmly in their position by means of the top lock-nut. If the two lock nuts are slackened, and the hand wheel turned, the upper cutter-block alone moves. The vertical scribing-spindle block, or 'cope head,' as it is called in America, moves with the horizontal cutter-blocks; but it can be adjusted separately, if desired. The upper cutter-block slide has lateral adjustment for tenons with varying shoulders, and a pulley and weight are arranged to take up automatically the slack of the driving belt. An apparatus for setting the knives is also provided, and altogether this machine is of an advanced type, and has much to commend it in its general details and convenience for working and adjusting.

Amongst the tenoning machines adapted for special purposes may be mentioned the American blind slat machine, patented by a Mr. Ellis. It is constructed to cut the cylindrical tenons and shoulders on both ends of a blind slat at the same time. Two sets of small circular saws are mounted on spindles running in brackets, each having lateral adjustment. Fitted to these brackets are two revolving disc guides, slotted through their sides to receive the blind slats and feed them to the saws. The slat being made to revolve, the periphery of the saw always cuts from the edge of the slat to the centre, thus forming a cylindrical tenon. It is adjustable to different lengths and widths of slats, and the size of the tenon can be also varied. The slats are fed by hand. For the same purpose Messrs. J. A. Fay and Co., of Cincinnati, make a very complete machine, with a self-acting feed; it is a combination of the patents of Ellis and Bickford. By an arrangement of the saws, two tenons are cut and divided at one operation. A pressure on a treadle causes the slat—which is fed end-ways through rotating discs or chucks—to revolve, and carries it to the saws; by releasing the treadle, the slat is stopped and fed to a gauge, and the driving belt is slackened, so as to slip and not drive. The plan of cutting tenons with circular saws or discs is generally confined in this country to circular saw benches, or the class of combination machines known as general joiners.

In designing tenoning machines with rotary cutters, care should be taken that the main column is of sufficient strength to overcome the vibration of the cutter blocks; a hollow or cored pattern is the best form. The table carrying the wood should also be cast in one piece, and both column and table fixed securely to a strong foundation-plate. The cutter blocks and bearings should have lateral and vertical adjustment; they can be fixed in dovetail slides, and adjusted laterally by a hand wheel and screw; these slides should be scaled, so that shoulders of unequal length can be cut to any desired gauge. The adze blocks should never be shifted

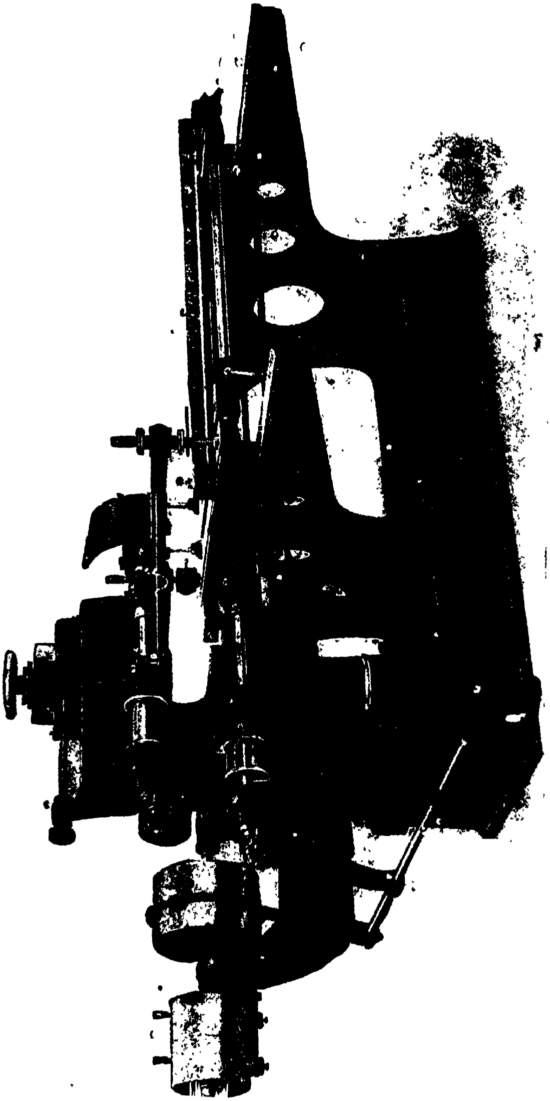


FIG. 25.—BUILDERS TENONING MACHINE.

on their spindles to effect this object, as the practice is both dangerous and uncertain. The scribing spindles for cutting double tenons, &c., should have both lateral and vertical adjustment. The cutters used should be of thin section, and fixed at an acute angle. We have found cutters with a steel face and wrought-iron back the most suitable, and less liable to accident. The carriage carrying the wood, which is traversed by hand, should be very light, and run on grooved rollers working on V-shaped guides. It should be fitted with a straight fence bar, and a quadrant for bevelled shoulders, both accurately scaled. A sliding stop for setting out lengths should also be provided, with a suitable cramp, fitted with a quick-threaded screw for holding down the wood. As the cutter-block spindles and bearings are made movable, a complete and uniform grip of the interlaced driving-belt must be secured; a grooved pulley, with rope and weight, as it works automatically, is perhaps the most convenient and simple arrangement, and is generally to be found on the most advanced type of American machines; on these machines, too, an apparatus is provided for setting the knives. The driving pulleys and belt should be made wider than is the practice on most machines, as the cut taken is considerable. We have found the belts known as 'Helvetia leather' are the best for this purpose, as they are tanned somewhat rough on the surface, are very pliable, and grip the face of the pulleys well. The spindles should be of steel, the bearings adjustable, and made of a hard gun-metal or phosphor bronze, and care should be taken as to their lubrication.

Fig. 26 illustrates a builder's tenoning machine by J. Sagar and Co., Limited, adapted for tenoning, cross-cutting, grooving, &c. It will make single, double, unequal or angle tenons and scribe the shoulders at the same operation. For cross-cutting a circular saw is mounted on the top cutter spindle and the sliding table used in the usual way. When used for grooving, a solid or expanding grooving block is substituted for the saw.

The main frame of the machine is of solid construction to secure rigidity in working, and the cutter spindles are arranged to run in three sets of phosphor bronze bearings. In contra distinction to the usual practice, the traversing table carrying the wood is of heavy construction—instead of light—and is fitted with roller bearings to reduce the friction.

The tenon cutter blocks carry four straight knives which are arranged to make a shearing cut and are so fixed on opposite sides of the block so as to divide the cut.

CHAPTER XIX.

'GENERAL JOINERS' AND COMBINATION MACHINES.

THE combining of the functions of several machines into one, under the title of 'general or universal joiners,' is of comparatively modern origin, and is more or less confined to this country, as we find very few machines of this class in use in America or on the Continent, although it is doubtless preferable, where the machines can be fully and constantly employed, that they should be separate and distinct; but as a large number of the building establishments in this country are not of sufficient extent to so profitably employ them, a well-designed combined machine, performing a considerable range of work, and produced in the first instance at a moderate cost, cannot but be of considerable value. On the first introduction of 'general joiners' they were very generally condemned, it being held that it was impossible to combine satisfactorily in one machine so great a range of work. This idea has now, however, been sufficiently disproved, although a large number of engineering abortions tended for some time to throw discredit on these very useful machines; we remember one production especially, made some years back by a firm of repute. In this combination no less than five distinct machines were crowded together on one bed plate. As these necessarily ran at short centres, were inconvenient to work, and cost nearly as much as separate machines, we can hardly see what can be urged in their favour. We need hardly remark that very few, if any, were made after the first one. We believe the first 'general joiner' was designed by a Mr. Whines, in the year 1858, and was made by the firm of Samuel Worssam and Co., of London, who exhibited one of them in the International Exhibition of 1862; it has, however, since then been much improved by various makers, and the range of its work extended. About this date also a Mr. Sketchley, of Weymouth, designed a light machine of a similar class, but they were not made in any great numbers. Mr. Thomas Ladyman, of Rochdale, a few years since patented a compact little machine, fitted to a 'cored' pattern framing. Two tables are arranged to rise and fall independently, the one being adapted for moulding and sawing, and the other for boring and slot-mortising. The saw table is arranged with a false top and stop piece for cross-cutting and for boring endways. A slide is also fitted for turning circular mouldings, as in a lathe. The machine has four speeds, ranging from 488 to 2,250 revolutions per minute, according to the work to be performed. In the year 1867 Mr. S. Worssam, of London, patented an improved general joiner. The improvements consisted, firstly, in the application to such machines of an apparatus whereby tenons may be completely cut in one traverse of the wood, and also the application to such machines of an arrangement for producing larger and more perfect mouldings, and an improved arrangement for squaring out the end of mortises left of semicircular form. This machine, with

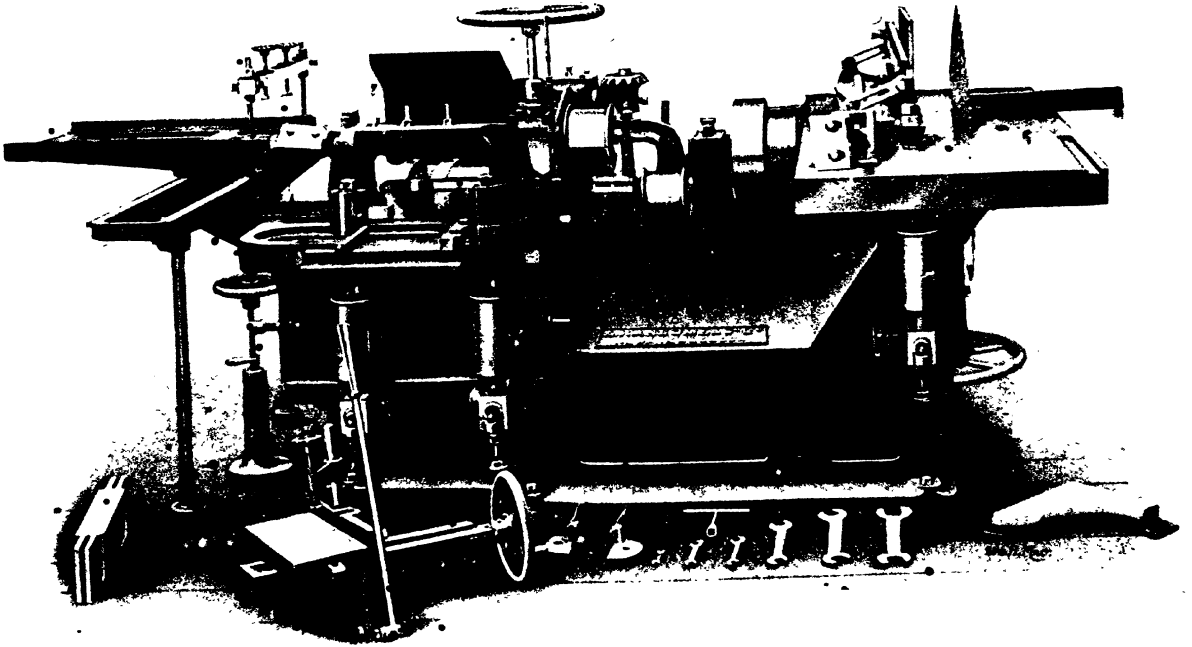


FIG. 26. RANSOME'S "COMPLETE JOINER.

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its various appliances, is capable of performing nearly the whole of the operations required in a joiner's shop, including sawing, planing, moulding, tenoning, mortising, boring, mitring, chamfering, beading, rebating, grooving, tonguing, &c. All these operations are performed independently of each other, or in conjunction. The planing and moulding are performed by rotary cutters, a self-acting roller feed carrying the wood beneath the cutters. The speed of this feed can be graduated to suit the nature of the wood being operated on. Tenons are formed either with circular saws or rotary cutters, as may be desired. The wood is held in a vertical position by a suitable cramp. The mortising is performed by a rotary auger, the wood being traversed up to it by a hand lever; the lengths and depths of the mortise are regulated by stops. Curved mouldings are worked on a separate vertical spindle. A traversing plate for cross-cutting, squaring, mitring, &c., is fitted to the saw table, and altogether this machine must be pronounced one of the most efficient of its class.

Fig. 26 illustrates a combination machine or complete joiner by A. Ransome and Co. Limited, and is designed for use in establishments where there is insufficient work for separate machines. It is adapted for sawing, planing, moulding, circular moulding, grooving, tenoning, mortising, boring, and dove-tailing.

The saw table is arranged to rise and fall for grooving, rebating, &c., and is fitted with an angling fence which can be turned over out of the way for cross-cutting.

The planing and moulding apparatus can be worked separately. The top and bottom cutter-block spindles are supported by bearings on each side and the wood is fed through the machine by a pair of driven feed rollers the top feed roller is arranged to rise and fall to suit irregularities in the wood. The bottom cutter block for planing is mounted on a movable slide to permit of the easy adjustment of cutters.

Tenons are formed by means of cutters, and double tenons can be worked, and the shoulders scribed at one operation by cutter discs mounted on one of the vertical cutter spindles. Boring and slot mortising are performed by means of augers screwed into the end of the planing block spindles.

Amongst combination machines, although differing essentially from the English general joiners, must be mentioned the American machine known as Climer and Riley's patent universal wood-worker. It partakes chiefly of the character of an outside cutter, moulding and planing machine, with extended spindles and cutter blocks, with two tables arranged with vertical and lateral adjustments on either side of the machine. The frame of the machine is cast in one piece, and the main cutter-block spindle is fitted with outside movable self-oiling bearings, and divided in the centre so that by means of a double friction pulley on the countershaft which carries two belts the ends of the spindle may be started or stopped separately or simultaneously, as may be required. The machine is arranged to operate on four sides of the wood at once, and the vertical side-spindles have vertical and lateral adjustments. The top cutter-block is arranged to be set to different angles, and all cutter blocks are made movable, and can be replaced by tenoning, rebating, panel-raising, matching, grooving, or other irons, according to the work to be performed. A ripping or cross-cutting saw can also be substituted for the cutter block, which, with the aid of an adjustable fence, converts the one side of the machine into a saw bench

It is also arranged for boring and slot-mortising, wave and circular moulding. The whole of these operations can be performed by one horizontal spindle, with different arrangement of tables, cutter blocks, or fences, according to the work to be carried out.

In designing a general joiner or other combination machine, the great point to aim at is simplicity of the mechanical arrangements, combined with ready adaptability to the various work to be performed, the whole being under the easy control of the operator. Mistakes have often been made in constructing the general details of too complicated a character, so that even when efficiency of production is attained it is more or less neutralised by the first cost, cost of working, keeping in repair, and the amount of skill required to operate. Some designers also strive to give their productions too wide a field of operation, losing sight of the fact that a moderate range of work, rapidly and accurately performed, must be held to be in every way better, and commercially more economical, than a greater variety of work indifferently turned out. By some engineers various appliances for joinery purposes have been added to the ordinary rising-spindle circular-saw bench. The planing is generally performed by means of a cast-iron disc, fitted with suitable cutters, which project slightly beyond the face of the disc. This disc takes the place of the circular saw, and the wood is fed by hand between its face and that of the fence plate. For squaring up and rough planing, this plan may be of some value, but for a finer class of work it cannot be recommended. Considerable skill and care is also necessary in operating, as the cutters require to be very finely sharpened and adjusted, or the work turned out is of a very inferior quality.

CHAPTER XX.

DOVE-TAILING MACHINES.

THE important operation in joinery known as 'dove-tail jointing' has for many years afforded ample scope for inventive genius. Numerous attempts to perform this operation by mechanical means have been made, but, with one or two exceptions, with scanty success. Dove-tailing with conical cutters was invented by Sir Samuel Bentham in 1793. Since that time numbers of machines have been introduced, but most of them have failed, either from inequality of wear in the cutters producing misfits in the wooden joint, from complexity of the details of the machine, difficulty of adjustment, or roughness of the work turned out.

About the year 1856 a Mr. Wimshurst took out a patent for dove-tailing with a series of cutters, the wood being brought up to the cutters from below. About the same time, too, a Mr. Burley took out a patent for a machine for cutting dove-tails by means of a series of reciprocating chisels, the wood being fixed on an adjustable bed, which could be inclined in either direction. The dove-tail 'pin' was formed in two cuts, the adjustable bed being inclined in the opposite direction after each cut was made. The 'dove-tails' were formed by a series of saws of varying diameters, the smaller saws being placed at either end and revolving on the same axis; two tables, set at an angle to each other and below the saws, carried the wood. These tables were arranged with a vertical motion, and the wood was brought up to the saws, which made an oblique cut; the wood was then placed on the opposite table, and a second oblique cut completed the 'dove-tail,' the depth of which was regulated by stops.

The "Armstrong" dove-tailer, originally introduced into this country from America by Thomas Robinson and Son, Limited, has never yet been surpassed for its exact work and high output. It is specially useful for all kinds of box making. See fig. 27.

The machine is semi-automatic, and very simple to operate. The entire dove-tail is sawn out by the machine, and forms a very close and strong joint when put together. The timber is cramped on a planed table, which is traversed to and fro past the saws by means of two screws, one of which moves the table forward, the other returning it at an accelerated speed. Both motions are controlled by a conveniently placed hand lever.

The table on which the timber is cramped is adjustable for varying thicknesses of timber. The saws which cut out the dove-tails are mounted on discs, geared together at an angle; these can be varied for cutting either the mortise or tenon dove-tail. The discs are graduated with figures, so that the position of the saws can be adjusted for cutting tight or slack dove-tails. Boards from $\frac{1}{4}$ inch to $1\frac{1}{4}$ inches thick can be dove-tailed on each size of the machine. The standard machine cuts dove-tails 1 inch pitch, but machines with other sizes and pitches are occasionally made.

Various single or multiple spindle-cutter automatic dovetailing machines for cutting open or blind dovetails have also been introduced.

Some fourteen years since Messrs. Greenwood and Batley, of Leeds, introduced a dove-tailing machine of American origin, which was arranged to work either by hand or steam power. The dove-tails were formed by a series of cutters or gouges, acting consecutively, each taking a small cut; these cutters were held in stocks, and were mounted in a movable slide, and traversed to the wood by a rack and pinion; no less than fourteen cutters were employed in this machine to make a perfect dove-tail.

In the Paris International Exhibition in 1867 M. Zimmermann, of Chemnitz, showed a dove-tailing machine consisting of three horizontal adjustable spindles mounted with cutters suitable to the dove-tail required. The wood was fixed in a vertical slide, and the counterpart cut by means of plain revolving discs, the table being arranged to angle in either direction to produce on the wood the proper degree of bevel.

In the year 1872 Mr. Tighe Hamilton, of Dublin, patented a series of improvements in machinery for cutting dove-tails. We illustrate in figs. 28 and 29 machines of recent construction.

These improvements, or we might more properly say inventions, possess very considerable originality of ideas. The dove-tails and pins are cut by means of the peculiar motion imparted to an ordinary circular saw. The saw is mounted on a spindle, part of which is bent at a such a degree of obliquity to its central line as is necessary to produce the angle of the dove-tails. This spindle is free to reciprocate as it rotates, and the saw swings to and fro in planes passing through a vertical diameter for cutting the tails, or through a horizontal diameter for cutting the pins. Any sized dove-tails can be cut, this being effected by causing the planes of the saw to intersect in other lines those that pass through the centre of the spindle. Fig. 29 represents a front view of the machine, in which the traverse of the head which carries the saw is horizontal, whilst that of the table which carries the boards is vertical. In fig. 28 these motions are reversed, that of the head being vertical and the table horizontal. The plane of the saw is kept in any desired position by means of an adjustable guide plate. The machines under notice are constructed on truly scientific principles, are easy of management, and possess less of complication than others of the same class, and, from their readiness of adaptation to varying sizes, spaces, and thicknesses of dove-tails, should be of especial value in cabinet work, in which the changes are often numerous.

Amongst numerous other machines designed to cut 'dove-tails' by means of conical cutters may be mentioned one designed by Mr. Ramsbottom, late of Crewe. In this machine the cutter spindle is arranged to revolve in a long cast-iron socket. This socket works in a slide fitted to a circular plate, attached to the main frame of the machine. The circular plate is arranged so as to be at right angles to the table while cutting the dove-tail, and can be set to any desired angle for cutting the pins. The cutter slide is brought to its work by a counterbalanced treadle, and by means of change wheels dove-tails of various sizes can be cut. Some years back a Mr. Evart patented in America a conical cutter machine carrying a number of cutter spindles driven by an interlaced belt. These spindles were mounted in a frame having vertical and diagonal movements, and were brought down to the work by a hand lever. The great objection to this and other conical cutter machines, especially when carrying a number of spindles, is the extreme difficulty of keeping the various cutters to one size, which, in actual practice, is found to be almost an impossibility, the result being that the pins and dove-tails produced are misfits. A machine, however, exhibited by Messrs. J. A. Fay and Co., of Cincinnati, U.S.A., at the Paris Exhibition, 1878, claims to have got over this difficulty. It was patented by a Mr. Stengel early in 1878; it is simple in its construction, and will cut a dove-tail in any kind of wood up to 1¼ inch by 14 inches wide, cutting both side and front at the same time. The cutter-spindle frames are stationary; the spindles revolve at high speeds, and can be adjusted laterally, to suit the depth of cut. The cutters are simple, are turned in a lathe, and always sharpened from the centre. Provision is also made for adjusting them, to compensate for any inequality of wear. A countershaft, fitted with cone pulleys fixed underneath the machine, drives the cutter spindles. The wood is fixed on a vertical and horizontal plate, and held fast by camb rollers. The 'pin' is cut on the horizontal table, and the 'dove-tail' on the vertical table. A hand lever moved up and down performs the operation, a slide moving forward at each alternate motion of the lever. The guides are so constructed that after being started it cannot be moved backwards at all, nor forward more than the distance arranged. If this machine proves itself capable of standing constant and heavy work, it is a tool that is much needed by cabinetmakers and others who require a machine that is moderate in first cost and easily adjustable to cut dove-tails of varying sizes and pitches. In 1873 Mr. Thomas Hall, of Northampton, U.S.A., patented an improved dove-tail joint, with machinery for making the same. In 1867 a Mr. Ganz patented an improved method of dove-tailing. The invention consists in operating simultaneously upon the two boards to be dove-tailed together, and in producing the 'pin' and 'dove-tail' by the same action of one set of cutters. In this machine two discs, fitted with plain cutters, are mounted on separate spindles, but are geared together by bevel wheels, so as to revolve in two planes of the same angle as the dove-tails intended to be cut. The wood is placed on a travelling slide, working on a horizontal bed.

CHAPTER XXI.

VENEER-CUTTING MACHINES.

As the supply of valuable timber becomes more and more exhausted so will the practice of covering the face of common wood with an ornamental veneer of other woods increase. The machines for cutting veneers may be divided into two classes—sawing and slicing. Sawing veneers has the advantage of preserving intact the grain and colour of the wood, but it has the disadvantage of cutting a considerable amount of timber to waste. The slicing process, however, is perhaps more generally in use. The wood to be cut is first steamed and then cramped in a frame, and operated on by a knife with a horizontal reciprocating motion, running obliquely across the wood.[1] Before the introduction of a machine for the purpose, veneers were cut by hand, the wood being secured in a screw press arranged for that purpose.

Bentham, in his patent of 1793, claims the cutting of thin veneers or scales by means of knives from blocks of wood previously steamed, and fully describes the process in his specification. In the commencement of this century Brunel took out a patent (1805) for a circular saw for cutting veneers, and since that date considerable attention has been given by engineers to the subject.

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[1] The steaming process, however, damages considerably the colour of some woods, and allows the glue to penetrate.

For cutting veneers Brunel employed a large circular saw, built up in segments and screwed on to a turned disc or flange: the holes through which the screws passed were made oblong, to admit of adjustment. When the segments were fastened to the disc, a layer of leather or paper was placed on the top of them, over which another disc was fitted, and the whole screwed up tight with bolts and nuts. These saws are so arranged that the bottom of their periphery is below the lower edge of the timber to be cut, which is fed forward by a rack movement.

Veneers seem to have been sliced by machinery in Russia some fifty years or more back, as Mr. Peter Barlow, in his treatise on 'Manufactures and Machinery in Great Britain,' 1836, mentions a process for cutting veneers with a knife as follows:—

The operation is begun by placing the timber from which the leaf is to be cut upon a square axle, when it is revolved and made circular by a turner's gouge. The blade of a plane of highly tempered steel, and rather longer than the cylinder, is fixed at the extremity of a frame of 6 or 7 feet in length, in such a manner as to exert a constant pressure upon the cylinder, and pare off a sheet of an equal thickness, which folds upon another cylinder like a roll of linen. The frame to which the blade is attached is movable at its lower extremity, and as it is charged it depresses in proportion as the mass diminishes in substance. That this depression may be progressive and perfectly regular, the inventor has appended a regulator to the machine, consisting of a flat brass plate, preserved in an inclined direction, upon which the frame descends as the regulator itself is advanced. The motion is communicated to the cylinder by several cog wheels, which are turned by a crank.

In the year 1831 Mr. Alexander Craig, of St. Bernards, Midlothian, took out a patent fo. 'certain improvements in machinery for cutting timber into veneers or other useful forms.' In one of these improvements Mr. Craig employed a circular saw, the operation of which is described by Hebert as follows:—The saw is made to traverse the whole length of the veneer to be cut, while it revolves on its axis in the usual way. It is made to traverse by means of a crank having a radius equal to half the length of the intended veneer, and a connecting rod of length sufficient to prevent too much obliquity of motion by carrying the band round a pulley stationed at a small distance, beyond the greatest distance of the saw from its driving drum. Though we have mentioned but one saw, there are a series of them attached to the saw frame, and put in motion by the same band, which is pressed down by an adjusting pulley between each pair of saws, that it may turn them with more certainty, by embracing a larger portion of the circumference of the riggers fixed on their axes. The log of wood from which the veneer is to be cut is suspended between centres similar to those of a turning lathe, so that it may be cut into one continuous veneer. It is evident that to produce an uniform motion in that part of the log in contact with the saws is necessary to its perfect action; and this the patentee has effected in a very ingenious manner. He puts into slow motion, by a species of gearing known by the name of the endless screw, a shaft having on its extremity a metallic cylinder, with a surface roughed in a manner similar to the surface of a rasp; and this cylinder, being pressed against the circumference of the log, will cause it to revolve at the same speed, whatever be its diameter. The specification is concluded by a description of an arrangement by which the saws are made to cut beyond their centres in a stationary log.

This is effected by attaching them on axes which do not project beyond the surfaces next the log. To the frame carrying these saws a descending as well as an alternating motion is given; and the veneer being, by a guide plate, made to fold back under the saws, it is clear that they will with facility cut to any required depth, without reference to their diameters.

About the year 1847 very considerable improvements in the method of cutting and laying veneers were introduced in America by Belter, a German cabinet-maker, whereby the variety and beauty of the work was much enhanced. Some years later a patent was obtained in this country by a Mr. Meadows for an improved method of bending veneers around sharp angles, such as those in mouldings.

Some few years since Mr. L. R. Hawes, of the United States, patented several improvements in machinery for veneer-cutting. The knife which cuts the veneer, contrary to the general practice, is made stationary, and the wood cramped in a sliding frame, which is arranged with a vertical reciprocating motion, oscillating slightly longitudinally at the same time, which is found to give a cleanness to the cut. A veneer is cut at each downward stroke of the knife, which is then drawn clear of the wood during its upward stroke, when it resumes its original position for another cut. All these motions are self-acting, and it is calculated to cut from 40 to 60 square feet per minute in almost any kind of wood usually employed for veneering. Some users prefer veneers cut round the annular growth rings of the timber instead of across. In this case the wood is steamed in the usual way, and made to revolve between centres: an extremely sharp knife is brought to bear on its face, thus obtaining wide and uniform veneers from small timber. In practice, however, it is found that some kinds of wood will not readily submit to this process without splitting, but with those that can be thus worked it possesses some advantages, as the figure of the wood is more entirely retained.

Veneers, too, are sometimes cut by a horizontal saw with a reciprocating motion. A single straight saw of very thin gauge and finely-set teeth is employed; it is tightly strung in a light swing frame, and sharpened to cut in both directions of the traverse. The wood is fixed in a slide which feeds vertically to the saw, and has a lateral movement to suit different thicknesses of cut.

In France veneers are very generally steamed and sliced by a sliding block and knife.

Operating as they do on very valuable woods, especial care should be taken in the design and exact construction of veneer-cutting machines, or considerable loss will be the result from inferior production. If a circular saw is employed, the disc should be balanced to a nicety, or the saw will not cut true, and the veneers will be of uneven thickness; the bearings too will rapidly deteriorate.

In slicing machines a back iron should always be fitted to the knife, which in large blocks should operate obliquely to the grain of the wood, and be so arranged that the whole length of the knife does not strike the wood at the same moment, as the shock thus occasioned is often considerable and the veneers cut are more liable to split.

CHAPTER XXII.

WHEEL AND CARRIAGE MAKING MACHINERY.

IN the manufacture of wheels and carriages on a large scale several special machines are necessary, in addition to modifications of some of those we have already noticed. Amongst these may be mentioned the spoke turning or dressing machine, spoke-driving machine, felloe-shaping machine, spoke-tanging and felloe-boring machine, wheel-facing machine, &c.; our space, however, will only permit us to give a brief *résumé* of some of the principal machines.

The principle of most of the machines now in use for turning or dressing irregular shapes, such as spokes, hammer handles, lasts, gun stocks, is contained in Boyd's patent, dated 1822. He claims in this patent the use of a model or dummy in conjunction with a blank of wood or other material, the outline of the model guiding the cutting tool to produce a duplicate from the blank. A shoe last is shown in the patent specification, as illustrating the principle claimed. From this machine, or, more correctly speaking, from this principle, numerous machines for analogous purposes have since that date been from time to time brought out.

Some five-and-twenty years ago a machine for dressing spokes, &c., with the grain of the wood was patented by a Mr. Hughes; the spoke was fixed on a table, which was traversed beneath the cutter by means of a rack and pinion. The cutter-block spindle was made hollow, and arranged so as to allow the cutters to traverse to or from one another as they were acted on by a model spoke, and the frame carrying the cutter block was pivoted on one side, which allowed it to rise or fall as desired.

In the year 1845 a machine for carving and copying irregular forms was introduced by Mr. Jordan, of London. In his machine the wood to be shaped and the model or 'dummy' are fixed on a horizontal table, running on wheels transversely on another table or frame, which was arranged to move in a longitudinal direction, so that by the straight-line movement in two directions the table could be made to have a motion in every part of its own plane. The model and wood to be shaped were made to swivel on centres, and so arranged that by means of a lever they could be turned simultaneously on their axes. The cutters were carried on a vertical slide, and made some 5,000 revolutions per minute; this vertical slide was raised or lowered to the work, which was fixed on the travelling table beneath by means of a treadle. A tracer guide acting on the model produced by the aid of the cutters facsimiles in the piece or pieces of wood.

Some of the greatest improvements in automatic lathes for turning irregular shapes were made and patented by Mr. Blanchard, an American, many years back, whose machine was undoubtedly one of the most remarkable inventions of the day; these have again been modified and re-patented by Gleason and others.

An improved form of Blanchard lathe, manufactured by Messrs. J. A. Fay and Co., of Cincinnati, U.S.A., and especially adapted for turning spokes, is deserving of notice, as it contains several features of interest.

The cutter block is fixed to a travelling bed, which is worked by a worm feed; the feed is adjustable for tapering work, and can be stopped at any desired point by a buffer which is attached to the frame. The cutter block is fitted with eight knives, which are arranged to give gradually 'finishing' cuts, thus leaving the spoke comparatively smooth when it is taken from the machine, consequently requiring little extra finishing on the buffing machine or sand belt, which is used to remove the marks of the cutters from the wood and give it a perfectly smooth surface to receive the varnish or paint. The vibrating frame is fitted with cut toothed gearing for rotating the model and wood to be shaped, and the vibrating rests are faced with steel and kept in position by a steel spring. The movable centre is worked by an eccentric and lever, and kept in any desired position by a ratchet. The cutter-block belt travels over a long iron drum placed below the machine, and, although shaping only one spoke at a time, this lathe is speeded to turn out as many as 900 spokes per day, which, if the finish is satisfactory at that speed, must be pronounced a very large number. The cutters are arranged to work across the grain of the wood.

In the improved Blanchard lathe for turning spokes patented by J. Gleason, of Philadelphia, U.S.A., some thirteen years since, the points of novelty claimed are the use of centres operated by an eccentric lever instead of a mallet, and the introduction of a lever for releasing the spring which keeps the vibrating frame in contact with the model or 'dummy.'

In the year 1863 Mr. H. Wilson, of London, designed and patented a multiple copying machine. The principle of using a model in conjunction with blanks was still adhered to, but instead of one a number of duplicates were produced at the same time. In this machine a model spoke and four pieces of wood are mounted in separate adjustable centres or poppet heads, which are fixed to a sliding table, arranged to travel by a screw feed beneath the cutters. The cutters are fitted on separate blocks, but are mounted on the same spindle, which revolves in a counterbalanced swinging frame. The principle of working pursued in this machine differs from the ordinary 'Blanchard' or other lathes, as in this case the cutters revolve in a fixed position, whilst the wood itself is made to revolve and travel beneath them; the reverse of this is usually the case, the cutters themselves being made to travel and the wood to revolve in a fixed position. The cutters used are perfectly flat, and are arranged to cut with the grain of the wood. From our experience we cannot recommend the plan of cutting with the grain of the wood, as, unless the grain is very straight and considerable care is exercised, large splinters are apt to be torn away, especially at the finishing of a spoke. With machines arranged to work across the grain this is not the case, but these spokes, however, take more finishing after they have left the lathe.

A very simple and efficient hand-power machine for centreing and boring wheel stocks or hubs was patented in the year 1868 by Messrs, Silver and Denning, of Ohio, U.S.A. It was arranged to adjust and hold the hub in position whilst being bored; this was secured by a kind of chuck frame, consisting of three equidistant radical arms furnished with dove-tail slots, in which worked adjustable jaws with corrugated faces for gripping the hub. These jaws were set in or out simultaneously by means of bevel gear. The boring spindle or mandrel was fitted with a feed nut, made in halves and of somewhat peculiar construction; the upper part of boring spindle, which worked in the nut, was cut with a feed screw of about two threads to an inch. An adjustable gauge for regulating the depth of the hole to be bored was fitted to the boring spindle. When a hub is to be bored it is secured by the jaws, the gauge is set at the right height on the boring spindle above the feed nut, the boring spindle is turned by a handle similar to that used with an ordinary auger, the boring tool being fed by the beforementioned feed-nut till the gauge comes in contact with the cap of the nut. A set screw is then loosened, which allows the feed nut to turn with the boring spindle, forming with a suitable cutter a square shoulder at the bottom of the hole.

Very few important improvements, that we are aware of, have of late years been introduced into machines for turning spokes. At the International Exhibition at Paris, 1878, several multiple copying lathes were exhibited in the French section. In the machine shown by Messrs. Gérard, of Paris, the cutters were fastened directly on to the cutter spindle, without any block or other provision being made. A very neat and simple arrangement was also provided for centreing the spokes or other work. A multiple copying lathe, especially adapted for shaping wooden shoes, or *sabots*, as well as spokes, was also exhibited by M. F. Arbey, of Paris. This we illustrate (fig. 30). Its action will be easily understood from the engraving. This machine is arranged to shape six articles at one time, the model which is required to be copied being mounted in centres having rotary and horizontal movements, and three blanks of wood being mounted in like manner on either side of it. The cutters operating on the wood are mounted in a swinging frame immediately over the blanks, and when set in motion are guided in their action by means of a tracer or feeler travelling over the model, the swinging frame thus rising or falling as required, and the cutters produce in the blanks the exact shape of the model. The cutters operate with the grain of the wood, and the spokes or *sabots* are traversed horizontally beneath the cutters by means of a slow screw feed.

After the spokes are shaped from the rough timber they are passed on to a tenoning machine, which is fitted in addition with a circular saw and gauge, which reduces them to one uniform length. They are afterwards passed on to a spoke-buffing or glass-papering machine. This machine consists of two endless belts, covered with ground glass of different degrees of fineness, running over two adjustable pulleys. The spoke is pressed on these belts by hand, the coarser grit removing the marks left by the cutters of the shaping machine, and the finer grit giving it a smooth surface.

Where large numbers of spokes are 'buffed' a great amount of dust is created, which floats about the workshop, to the detriment of the health of the workmen and the machinery employed. To obviate this a simple pneumatic apparatus for conducting away the dust can easily be secured by arranging a small fan blower—say, with an impeller of about 16 in. diameter, and running about 2,000 revolutions per minute—fitted with induction and delivery pipes. By these means the dust can be conveyed to the stoke hole or other part of the building. This system has also been introduced into saw mills for the removal of the shavings, sawdust, and chips made by trying-up, sawing, and the other heavier class of wood-working machines.

Amongst the other wheel-making machines may be mentioned a machine for driving the spokes into the wheel stocks, patented in America by a Mr. Hosler some eight years since. In this machine the blows are given to the spokes by a swinging mallet, worked by a cam motion, as if used by hand they are governed by the pressure of the foot on a treadle. The blows can be graduated from heavy to light, or from fast to slow; an adjustable guide is also fitted, which sets the spoke perfectly true before being driven. Another tool recently introduced in America is Corr's patent automatic wheel machine, which is arranged to drive, cut off, and tenon the spokes in the wheel, without removal after being once adjusted. For driving the spokes the wheel stock is fixed on a stud in the centre of a vertical frame. This stud has a movable outside bearing, worked by a lever. The spokes are driven by a mallet, operated by a spring and eccentric which forces the mallet down after it is raised by a cam. Attached to the main frame of the machine is an apparatus with lateral and transverse movements, for sawing and tenoning the spokes. This can be adjusted in its position to suit wheels of different sizes, and is so arranged that as one spoke is being driven another is being cut to gauge by a circular saw and tenoned. A hollow auger fitted with cutting lips forms the tenon on the end of the spoke. This auger is combined with the saw, and by depressing a foot lever they are both brought forward to the work, the saw operating first and the spoke being held between horizontal guides in line with the tenon tool; this is automatically moved by a screw, and the tenon is completed to any desired depth. The inventor claims that one man with this machine can drive, saw off, and tenon thirty wheels and upwards per hour.

Some manufacturers prefer the oval form of tenon on the ends of the spokes where they enter the felloe, as the risk of splitting in driving is lessened, and it is not found necessary to wedge this form of spoke to keep it in position. The felloes of the wheels are usually cut from the rough timber by a band sawing machine fitted with a radial arm. In America an arrangement of circular saws is often employed. Two concave saws are mounted on a spindle, one end of which revolves in a pivoted bearing, capable of adjustment and movement in a vertical plane on the axis of its bearing. The wood is fixed on a vibrating carriage, and is adjustable to or from the saws. A separate set of saws must be used for each sized felloe, as the curvature required on the saws is necessarily different.

The felloes are planed on an ordinary vertical double-spindle shaping machine; they are fixed in a radiating cramp, and the wood is first of all brought in contact with one set of cutters, which planes one-half of the inside and chamfers the edges; it is then passed to the other cutter block, which completes the operation.

By using two cutter blocks revolving in opposite directions the wood need never be cut against the grain; consequently the work turned out is of better finish. A cutter block revolving horizontally, for planing the edges of the felloe, and, where a large amount of work is turned out, a self-acting feed can be added to this machine with advantage.

A very useful machine in connection with wheel manufacture is Morris's patent wood-bending machine, introduced some few years since. The principle on which it is constructed is the bending by levers from the centre outwards. After the wheel is put together it is usually finished in a surfacing lathe, or in a planing and finishing machine especially adapted for the purpose. An outside-cutter moulding and planing machine can readily be modified to perform this work, the wheel being mounted on a separate vertical screw chuck fitted to a stand, with vertical, transverse, and angling movements. In the construction of a wheel no less than twenty different machines can be employed with more or less advantage.

CHAPTER XXIII.

CASK-MAKING MACHINERY.

MACHINERY for the manufacture of casks has of late occupied considerably the attention of engineers, and a number of labour-saving machines for the especial class of work required in a cooperage have been introduced, with very satisfactory results, and so complete are some of the plants erected that very little manual labour except putting together is necessary. Some of the earliest machinery erected in this country for the conversion of wood was devoted to the manufacture of casks and powder barrels. We believe the first patent taken out in connection with machinery for the manufacture of casks was that of Plasket and Brown, in 1811; but Mr. George Smart, of Westminster Bridge Road, is stated to have had a set of cooperage machinery in use some years previous to this date, but what its construction was there is no record, as far as we are aware, to show. Being one of the earliest efforts in this country in connection with the conversion of wood by mechanical means, we think it of sufficient general interest to append a short description of Plasket and Brown's machinery as described in Dr. Gregory's 'Mechanics.'

'First, the machinery for cutting the stave consists of a stout bench, having a board or platform annexed to it capable of being moved endways, to which another board is connected, so arranged as to be moved across steadily by racks and pinions or screws. The last board has a hollow part made in it, in which the stave board may be laid so that one edge of it may project clear beyond the edge of the first-mentioned board. A circular saw is placed either above or below the bench, having its axis at right angles to the line of motion of the first-mentioned board and opposed to the direction of the course of the projecting part of the stave board. This circular saw is made flat when the straight-edged staves are to be cut, and is dished, or of a spherical shape, when staves with curved edges are wanted. The board first mentioned is moved either in a right line or is made to assume a curved course by being confined in its motion by curved grooves or by curved rods moving against pins; and by the proper management of these sliding boards the stave board is cut by the circular saw of the shape desired. The machinery next used consists of a large lathe, in which the cask is turned in a vertical position when it is of a large size (after it is formed in the usual manner from the staves prepared as above described), being either fixed in a great chuck placed beneath it or in a cylindrical cage which surrounds it, fixed upon a strong upright arbor and revolving between collars, where it serves the office of a mandrel. In this lathe the chime and groove for receiving the head are turned in the cask by the application of a proper tool. When the cask is small, the cage is made to turn in a horizontal position instead of revolving vertically. The third operation is to form the head, which is pinioned together as usual, after having the pin holes made by piercers projecting from the mandrel of a lathe, the distances and depths of which holes are correctly regulated by gauges; it is then turned on a flat revolving table, from which points project to hold it fast, and against which it is held by another revolving piece that is screwed towards the first, where it is brought to the proper size of the cask by fit tools. The fourth operation is to turn the whole cask at the outside, for which purpose it is placed in a large lathe between two chucks, made to fit into the chimes, and attached to the head by points; and then the surface of the cask is turned smooth by a spoke-shave, or other fit instrument, held against it by a rest properly placed for the purpose. The patentees bend their wooden hoops for their casks in an expeditious manner by fastening one end of them to the circumference of a wheel, and pressing them against the wheel as it is turned round; they also describe a method of forming the projecting part in the bung staves of the small casks called bottles by means of flat or concave circular saws, which cut the face of the stave on each side close up to the projection; and, lastly, in giving motion to this machinery the inventors use any of the usual first movers and mill work, as may be necessary.'

Sir John Robinson, too, was one of the earliest inventors in connection with cask-making machinery. He proposed the plan of bending the stave against a curved bed, and jointing same by means of two circular saws.

In the year 1825 Mr. Samuel Brown patented a series of machines. The staves were edged by means of an ordinary circular saw, the wood being fixed and pushed through the saws in a slide having a curved motion and resting against a fence or guide consisting of a flexible bar which could set to any curve desired in the stave. He also used a system of expanding cutters for chiming, &c.; they were fixed on a vertical spindle and traversed round the inside of the cask.

Some of the most important improvements in cask-making machinery are those of Gibbs and Gatley, engineers, London, whose patent specification, dated 1855, possesses several features of interest to engineers, as more than one of the ideas therein contained has been the subject of recent patent rights. They claim briefly certain arrangements of machinery for cutting two staves from one piece of wood, the part which is flattened out between the two staves forming a portion of the head of a cask; the arrangement of machinery for cutting the edges of staves to their proper curves, and for cutting the grooves at the ends of a cask to receive the head, and also the bevels at the ends of the cask. They also claim the construction of an ordinary vertical saw frame in such manner that one set of saws with their frame shall at all times balance another set of saws and their frame, and also the application of a saw of the form of a segment of a circle for cutting veneers. The plan pursued in cutting the cask staves is decidedly ingenious. Two straight or mill saws, somewhat narrower than those used for ordinary sawing, are mounted in an ordinary sawing frame having a vertical reciprocating movement. The saws, however, are not fixed to the cross-heads in the usual manner, but mounted in two small separate frames. Each of these frames consists of two vertical guide-rods, attached at their upper and lower ends by means of bolts and nuts to wrought-iron plates. In each of the cross-heads is formed a vertical mortise, through which the pins which carry the saw pass. These pins are fixed at one of their ends to the plates, and at the other to the saws. Therefore, if either of these pins be moved in the mortises, the saw will move with it; consequently the two saws can be made to diverge from each other till one-half of the staves are cut, and approach towards each other till the other half are cut. This movement is effected by means of two guiding pieces and four guiding sockets, acting in conjunction with springs; these are so arranged that when the machine is set in motion the guiding sockets will roll along the surface of the guiding pieces and follow their curvature, being forced apart by the springs till one-half of the staves are cut; they will then gradually approach each other till they assume the position from which they started. By changing the guide pieces staves of any desired curve may be obtained.

Following Gibbs and Gatley's patent various improvements were introduced into cask-making machinery by Rosenberg, Green, Robertson, and others.

Green introduced a tolerably complete machine for 'backing' and 'hollowing' the staves. In his machine the stave was arranged to travel on a narrow roller by means of a fluted feed-roller, fitted immediately over it and pressing the stave upon it. The narrow roller supporting the stave revolved freely on its own axis, and was arranged between two revolving cutters, which gave the desired shape to the stave.

In the year 1852 some important improvements in cask-making machinery were patented by Robertson, of Glasgow. In making casks and other wooden vessels according to this invention, the rough staves were first steamed in the usual way, to cause pliability, and then, in order that the irregularities or bends in the wood might be nullified, the stave was screwed up by its flat side against a fixed bearing surface or against rollers, so that, when passed into the sawing machine, the wood might be accurately cut. A self-acting arrangement was employed in connection with these retaining or flattening screws, for the purpose of slackening off these holding details as each approached the cutting edge. At the same time a series of cutters was arranged to work on the exposed side of the stave, for the purpose of dressing that surface to the form required. As the stave moved forward it was first sawn on the edge by a circular saw, to take off the 'over wood' to the required curve; it then came against a set of rotatory cutters, which finished the surface. At the same time a set of cutters worked over the top of the stave on its flat surface. Then, when this flat side and one edge had been so shaped, the stave was reversed and the other edge and side similarly treated. Several staves can be done at a time. When the staves are piled together, or when the 'cask is raised,' the upper ends of a stave being surrounded by a hoop, the mass of staves is put into a press, to compress the bilge of the cask and bring together the bottom or opposite loose ends of the staves.

Robertson's machine for bending or 'trussing' the staves is also worthy of notice. The staves were first steamed at a temperature of about 220° Fahr. The trussing machine consisted of two iron cones; the inside periphery of each was made to fit the outside curve of the cask when finished. The upper cone was widened at its lower extremity, so as to surround the staves, which were fixed up into it by hydraulic pressure. Truss hoops were let into recesses flush with the inner periphery of the cones, which were arranged to open by hinges.

Messrs. E. and B. Holmes of Buffalo, U.S.A., also designed a very complete set of barrel-making machinery, some of which possessed considerable originality. The staves were jointed and cut to the required curve by means of a revolving concave wheel fitted with a radial cutter.

The groove for the head and the bevel at the ends of the cask are produced at one operation—viz. by the slow revolution of the cask on an axis simultaneously with the rapid revolution of cutters, which are held in contact with the inside of the cask and guided by a blank roller. The whole of the mechanical arrangements contained in the specification must be held to reflect the highest credit on the inventors, more especially when it is borne in mind that at that date wood-working machinery had scarcely any existence.

Owing to the development of the commerce in petroleum a considerable impetus has been given to the manufacture of barrels in the United States, and many factories where they are manufactured in immense numbers are now in existence. This greatly increased demand naturally turned the attention of American engineers to the further improvement and development of cooperage machinery, and a number of labour-saving tools of more or less novelty has been the result.

In the year 1865 J. S. Thompson, of Glen's Falls New York, took out patents for a series of machines, some of which possessed considerable ingenuity.

One of these was arranged to saw the staves to an uniform length, croze their inner ends for the reception of the barrel head, and chamfer the end edges at one operation. In the centre of the machine a spindle was arranged with a circular saw, chamfering cutters, and V-shaped crozing cutters at either end. Two spindles, one on each side of the saw spindle, carried wheels, over which worked chains. Vertical lugs were attached to the chains at equal distances, and the staves were fed horizontally to the saws and cutters, being held firmly in position by adjustable plates bearing on the back and front of the stave. One set of these plates rested on springs, which were arranged to yield to varying thickness of staves.

Another of these machines was designed for stave-jointing; its arrangement was briefly as follows:—The top of the frame of the machine was made concave, corresponding with the bilge of a cask. On this frame a carriage was arranged to travel longitudinally. Fitted to this carriage by pivots at each end was a frame which held the staves, which were placed on edge by means of a cam lever operating on a spring. In the centre of the machine was a horizontal cutter-head, driven by a vertical spindle, which jointed the staves, the necessary bilge being given by the concavity of the slides, and the bevel by the position of the carriage which held them. A strap attached to this carriage winds on a roller, and draws the carriage with its load of staves over the cutter head; when the jointing is performed the carriage is run back by a weight, which is thrown into action by the release of the winding roller, which is connected with its spindle by a clutch.

The third machine of this series is one which is arranged to saw and chamfer the head at the same time. The tools consist of a concave or dish saw and a cutter block, both fitted on the same horizontal spindle. The boards intended to form the barrel head are placed on a circular plate, which is geared underneath; directly over this plate is a circular cramp, worked by a screw and hand wheel, and arranged to rotate with the circular plate. The circular plate, gear, and supporting bracket are pivoted to the main frame of the machine and are arranged to cant to any angle. When the necessary boards are secured on the circular cramp-plate, the whole is canted towards the saw and cutter, the concave saw chamfering one edge and the cutter block the other, the circular plate being at the same time rotated either by power or a pinion and handle, thus causing the whole of the periphery of the barrel head to be operated on by the saws and cutters. A set of cask-making machines was exhibited in the Paris Exhibition, 1867, by Cool, Ferguson, and Co., Mass., U.S.A.

Following these inventions, nothing noteworthy was produced for this especial class of work for some years. When the band saw was reintroduced by M. Périn, of Paris, in 1855, it was more or less adopted for cutting out the staves and bottoms of casks. Another French engineer, M. Arbey, of Paris, modified several existing machines, including a planing machine for rounding the staves and planing up the bottoms, a vertical moulding machine for chamfering the bottoms, and a tonguing and grooving machine for jointing them. He also invented a machine acting with spiral knives for chamfering and recessing the ends of the cask after it has been put together.

During the last ten years, owing chiefly to the rapid increase in operatives' wages, a number of patents for improvements in this class of labour-saving machinery have been taken out by Robinson and Smith, Woodley and Anderson, Slater, Thorneley and Buxton, Lyle, Hewit and Hays, Gerard and Thulier, Gedge, Ransome, and others.

Mr. Abram Lyle, in his patent, dated 1871, claims improvements in a machine for dressing staves. In his machine the stave is gripped between and fed along by short massive rollers, arranged with their axes vertical, whilst in the centre of the row of feed rollers is a revolving spindle, having fixed on it the cutters for dressing the stave. The cutter spindle is carried in a bracket arranged to slide in guides below a table, and is adjustable. The feed rollers on the same side as the cutter spindle are fluted, and are driven by means of worm wheels fixed on their spindles below the table, gearing in with worms fitted on a horizontal shaft, which is driven from the first-motion shaft. The feed rollers on the other side of the stave are held in forked blocks set in boxes containing strong springs, which are adjustable by means of screws. The rollers on both sides are made sufficiently strong, and the pressure applied is sufficiently great, to straighten any twist in the stave passing through.

Messrs. Robinson and Smith, of Rochdale, patented in 1873 a method of making bungs or shives for casks by means of a cylindrical saw and rotary cutter; and Messrs. Hewit and Hays in 1875 patented a machine for cutting staves by means of two circular saws placed side by side, and arranged with such a motion that when a stave is passed between them the two sides are cut off at the same time and the proper bulge given to the stave.

Improvements in cask-making machinery of some importance have been introduced by Messrs. Thorneley and Buxton, of Burton-on-Trent. They patented in 1875 an improvement in machinery for jointing staves. This consists in centreing wooden staves both in the direction of their width and length by means of an apparatus fixed on or to machinery used for jointing or edging such staves. The former is attained by means of a rotating cam, which opens the dressing knives or cutters so as to receive the widest stave between them, and closing the said cutters on the edges of such stave, of whatever width, by means of a weighted lever; and the latter is accomplished by lengthening out or shortening the centreing gear, so as to bring the centre of the stave to the centre of the said cutters. Thorneley and Buxton patented also in 1878 machinery by which wooden staves for casks are 'hollowed' and 'backed' at one and the same time. The cutters, guides, and bed on which the staves are dressed are so arranged that bent, twisted, or otherwise misshapen staves are easily worked. The cutters in this machine are raised or lowered by means of a cam or eccentric for hollowing staves to a gradually varying thickness from their centre towards each end.

In the year 1874 a series of improvements in cask-making machinery of some novelty was patented by John Woodley and John Anderson. The first part of the specification relates to apparatus for cutting the edges of staves to the desired shape, or the process commonly called jointing. For this purpose each stave is successively placed on the table on or in a groove of which an endless chain traverses, with projections, one of which, by acting on one end of a stave, drives it forward between a pair of radial arms or shafts at angles one to the other, carrying cutters to produce the desired angle to the edges. The relative position of the shafts is variable by right and left hand screw motions, by which these angles may be varied. These shafts are supported in a frame capable of movement transversely to that of the stave, to adapt the cutting to variations in width of the stave. These motions are effected by cams or tappets, and rotations to the cutter shafts by straps or bands. A saddle piece held by the attendant and a stationary roller aid in guiding the stave to the cutters, whilst weighted lever-arms with rollers hold the stave during the cutting. The invention also relates to apparatus for hollowing the inside surface of the stave. For this purpose each stave is, as in the last apparatus, placed on the table, so as to be acted upon by one of a series of projections from an endless train chain, by which it is moved into position to be cut by rotary cutters, driven by a band or strap, and is guided whilst moving forward by a template or roller or rollers. Weighted guides and a weighted pressure roller guide and aid in holding each stave in position during its traverse.

The cutting of the outer surface or 'backing' of the staves is effected by each stave being moved forward by a similar endless chain on a table, so that the outer surface of such stave may be acted upon by other rotary cutters, the motion of the staves being aided by weighted pressure rollers and guides. The invention also relates to means for effecting the desired bevelling of the edges of the heads of the cask. Pieces of wood jointed together to form a head are placed between, and so as to be held by, pins between two plates capable of sliding sideways on other face plates. The axis of one of these face plates is hollowed to receive through it the axis or spindle of its sliding plate. Rotary motion is given to this hollow shaft to cause the rotation of the several plates and the 'head' held between them, but during this motion other motion is given to the axis of the sliding plate, carried by the plate affixed to that hollow shaft, so as to cause the head to revolve in an oval direction, so that its edge may be cut by the bevelling cutters to an oval form, capable of adjustment as to extent. The invention also relates to means for planing the edges of the separate breadths of wood to form the heads. For this purpose a table and endless chain, such as before referred to, are employed to conduct the pieces between a pair of rotary cutters, and the distance apart of the axes of these cutters is regulated to the width of wood under operation by a pair of pins or projections carried by frames supported by right and left hand screws, such frames also carrying the axes of the cutters.

In the International Exhibition of Paris, 1878, Messrs. A. Ransome and Co., of London, exhibited specimens of their lately designed machinery for the manufacture of powder barrels; but, considering the warlike and beer-drinking proclivities of the age, machinery for the rapid construction of casks was conspicuous by its absence. During late years, however, it must be admitted that this class of labour-saving tools has made very great progress.

CHAPTER XXIV.

SAW AND CUTTER SHARPENING MACHINES.

THE sharpening of saws other than by hand labour is of modern origin. The fly press for punching and gulleting saws has been in use for many years; but a machine for topping, bevelling, and gulleting without the aid of a file was first introduced into this country about the year 1865. This sharpening is performed by means of a revolving emery disc (or, more properly speaking, a disc containing a composition of emery, india-rubber, sand, &c.), travelling at the speed of some 5,000 feet per minute at its periphery. A serrated steel disc has also been tried, but with unsatisfactory results, except in the case of band-saw blades, when, in the Paris International Exhibition, 1878, Martinier's patent machine for this purpose was tolerably successful, and attracted some attention. Messrs. Greenwood and Batley, of Leeds, first made Parnacott's patent saw-sharpener about the year 1865, and a few years later a Saunders's patent machine of French origin was introduced.

A new form of vitrified wheel has lately been tried, with considerable success. In this wheel the material by which the grains of emery are united in a solid mass is somewhat softer than the emery, and allows the worn-out particles of emery to break away and new ones to present themselves. In the course of manufacture these wheels are burnt and baked, and can be made to present any degree of hardness required.

In 1874 Mr. James Harrison, of Tattenhall, Cheshire, took out a patent for improvements in sharpening and gulleting saws. He claims as novel the arranging of the vice which holds the saw to be sharpened in V slides in a similar manner to the slide rest of a lathe; so that by means of a rack and pinion or screw adjustment the operator is enabled to traverse the saw and bring it into contact with the revolving emery wheel, which is mounted in a frame that remains stationary, instead of being arranged to traverse, as heretofore, for the purpose of adjustment, whereby a much steadier cutting action is obtained. We presume the novelty claimed in this patent is the application of a slide-rest vice to the special purpose of sharpening saws; but it affords an apt illustration of the very slender grounds of novelty on which patents are often applied for and granted in this country.

In the most improved machines now in use the emery wheel is mounted on a small steel spindle, running in centres and fitted in a counterbalanced swinging carriage. This carriage can be brought down to the saw by hand, and by means of a quadrant can be set to an angle to give any desired lead to the tooth. Where a boy is employed to work, an arrangement can be fitted to regulate the depth of the gullet and the pitch of the teeth. The saw to be sharpened is held in a vice having both a lateral and transverse motion. The countershaft is usually placed at the back of the main framing of the machine, which should be cast in one piece. The band giving motion to the emery disc passes over an idle pulley, and then directly on to a small pulley on the emery disc spindle. In a well-constructed and well-worked saw-sharpener the use of the fly press for gulleting should be entirely dispensed with. If, however, a saw should be broken, it can be used with advantage to cut it down and punch new teeth. The economical advantages accruing from the use of a saw-sharpener are considerable, it being capable of turning out at least as much work as six men sharpening by hand, and of better quality, and the lead of tooth and depth of gullet can be exactly proportioned. Its use also should effect a total saving in files, although some operators persist in 'touching up' the saw with files after it has left the machine. This practice should always be discouraged, as the cutting action of the disc, in addition to engendering heat in the points of the saw teeth—owing to the rapidity of its motion through the air—causes a cooling process to go on at the same time, which, when the sharpening is completed, leaves the teeth with a considerable amount of hardness; they consequently wear longer than if left with their 'skin' soft, as is the case in hand-sharpening. The quality of the emery discs should be undoubted, and of not too coarse a grit, except for heavy, rough work. On the early introduction of this machine considerable disappointment and loss was occasioned from the unreliable character of the discs then supplied: this is now no longer the case. Fig. 31 represents a compactly designed machine, arranged to sharpen both circular and straight saws, by Messrs. Thomson, Sterne, and Co., Limited, of Glasgow.

For sharpening band-saw blades, up to the present time the only machine that we are acquainted with is Martinier's patent, the first of whose machines which

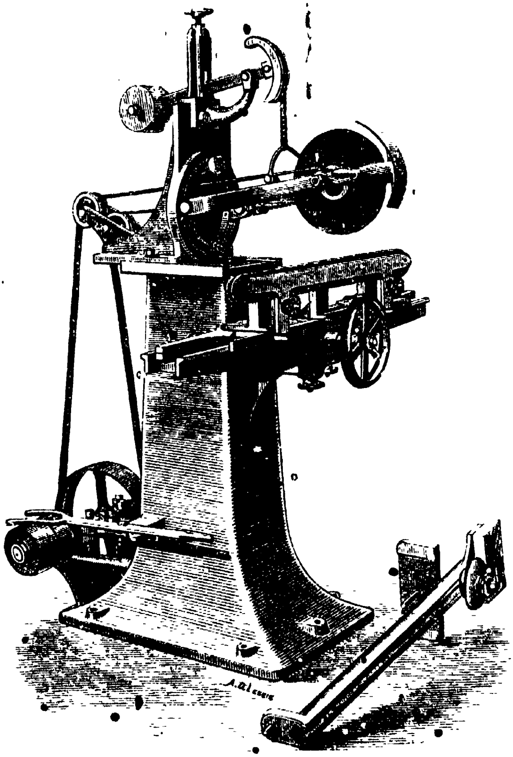


FIG. [illegible]. SAW SHARPENING MACHINE.

was adapted for both sharpening and setting the blades was exhibited in the Paris International Exhibition, 1878. It is ingenious, but somewhat complex in its construction. Whether it will stand the test of time remains to be proved. We believe it has not yet been introduced into this country. The saw blade is placed round two pulleys, and is sharpened by a small revolving disc of steel, which is bevelled on one edge and serrated. The saw is brought forward a tooth at a time by means of an automatic feed, and held in position by a spring, which is released as each tooth is sharpened, when another is advanced. A stop-piece is fitted to the saw, which automatically throws the machine out of gear when the sharpening is completed. A small apparatus was attached for setting the teeth, but of no special novelty.

Messrs. J. A. Fay and Co., of Cincinnati, U.S.A., exhibited a clever little saw-setting machine, which gave to the teeth of the saw a blow similar to that given by the workman's hammer, instead of a pressure, as is usual in most machines for this purpose. It is capable of vertical and lateral adjustment, according to depths and widths of teeth and gauge of saw. The amount of set is varied by means of an adjustable steel pointer, which is bevelled at the bottom to the maximum set. The saw is set two teeth at a time, and fed forward by a paul and lever adjustable to the pitch of the teeth.

For sharpening planing and moulding irons an ordinary Yorkshire grindstone, with a water of Ayr or similar class of stone attached, is still generally used. Several attempts have been made to substitute emery discs, and we illustrate (fig. 32) a little machine recently patented by Mr. Handyside, of Glasgow. In the centre of the machine is a wheel suitable for grinding straight irons, and at one end of the spindle four emery wheels adapted for sharpening moulding irons are fitted; at the opposite end of the spindle is an emery hone for finishing purposes. The water necessary is supplied by means of a small pump, worked from the countershaft shown at the back of the machine. Several machines were shown at the recent exhibition in Paris by

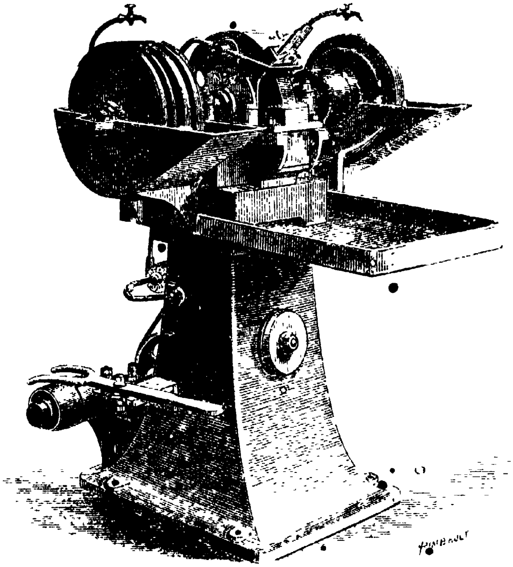


FIG. 32.—HANDYSIDE'S PATENT TOOL GRINDER.

F. Arbey on which were fitted small revolving emery discs, arranged to sharpen the plane irons without removing them from their blocks. In the use of emery for this purpose very great care must be observed, or the cutting edge of the iron will be made too hard, and consequently chip in the working.

For sharpening long plane-irons a grinding-rest, with lateral and transverse movement, should be attached to the grindstone; the iron should be held in a frame arranged to set to any desired bevel, by which means the longest irons can without difficulty be ground perfectly true.

It is very necessary that the grindstone itself should be in good order, and true on the face. For many years, when the stone became untrue, it was the custom to turn it up with a pointed steel tool. This plan, however, is very wasteful, and in many establishments has given place to handy little apparatus for dressing up grindstones, patented by a Mr. Brunton some five years since. It consists of a steel disc bevelled to a cutting edge on one side, and keyed to a spindle which revolves in a socket attached to a plate. The cutting disc and plate are made to traverse across the face of the stone by a hand wheel and screw. The disc is fixed at an angle to the stone, and is pressed against it, the stone thus causing the disc to revolve at a speed on its cutting edge equal to that of the stone. Any degree of feed can be put on the cutting disc, which quickly removes inequalities, leaving the face of the stone perfectly true, causing the smallest amount of waste to the stone and effecting a considerable saving in time.

For grinding moulding irons some four Bilston or other sandstone grindstones, of some 18 inches diameter, should be mounted on a spindle revolving in a trough. These should be turned up to fit the outlines of the various moulding irons. In addition to these four stones, two other fine grit stones are usually attached, to give the irons a fine cutting edge after they have been reduced on the shaping stones.

CHAPTER XXV.

HAND-POWER MACHINES.

ONE of the most general operations in joinery is that of mortising, and there are few but the very smallest establishments that cannot employ a machine driven either by steam or hand economically. It is a matter of some doubt when a machine for mortising was first made in this country. Probably rotary machines driven by water power were in use at the end of the last century. However that may be, Bentham in his specifications in 1793 distinctly claims both reciprocating and rotary machines; and it seems that he, in connection with his brother, Jeremy Bentham, was commissioned some few years later by the Government to fit up several of the dockyards with machinery, amongst which mortising machines are mentioned. In the first thirty years of this century little or no progress was made, and very little appears to have been done in manufacturing machines for sale. Even in the year 1848 the manufacture was confined to a very few firms in this country, amongst which we may name the following as the most important :—Worssam, London; Horn, London; Powis, James, and Co., London; Robinson, Rochdale; Furness, Liverpool; McDowall, Johnstone; Forrest and Barr, Glasgow; and most of these

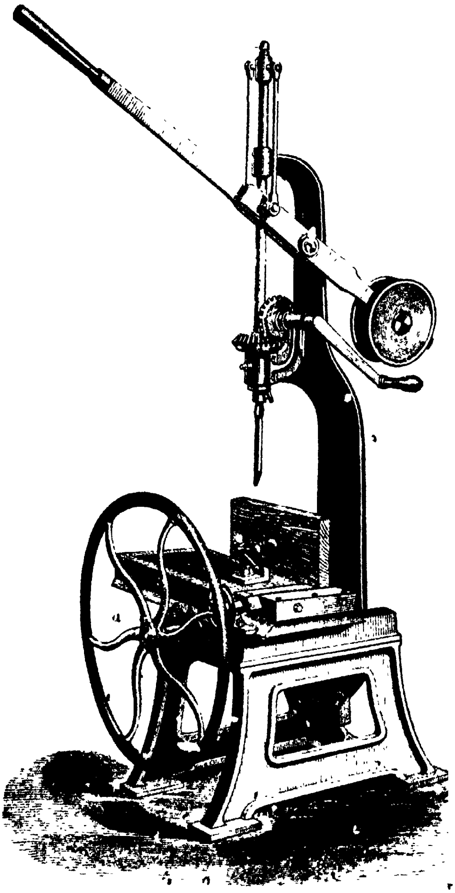


FIG. 33.—HAND POWER MORTISING AND BORING MACHINE.

made only on a very small scale. When we compare the large establishments now in operation, and the great range of machines turned out, we cannot but admit that sawmill engineers have, to say the least, kept pace with any other branch of engineering.

A mortising machine worked by the foot was invented by Mr. John Mortimer, of Aberdeen, in the year 1847; and the hand-power lever mortising machine was introduced into this country from America by Mr. Coulson, of York, about the same time.

The mortising and boring machine we illustrate herewith (fig. **33**), although somewhat modernised, is substantially the same as one brought out by Messrs. Wilson and Lewis, for the firm of Powis, James, & Co., in the year 1852, and for the combination of the operations of mortising, tenoning, and boring in one machine letters patent were granted to them. The illustration does not show the tenoning arrangement, which, however, is easily added. As a strong, well-made machine it compares favourably in the ratio of six to one against hand labour with chisel and mallet; the wonder is, in these high-pressure days of cheap production, that they are not more universally used than they are, as they would pay a handsome interest on the amount invested if they were idle one-half of the year.

The action of the machine is easily understood. Motion is given to the chisel by a counterbalanced forked lever (worked by one or both hands), which is connected with a gun-metal cross-head at the top of the vertical spindle by two wrought-iron double eye-pieces. The wood to be mortised is placed on a table immediately beneath the chisel. This table can be worked by the large hand-wheel, which is perhaps the most convenient for light work, but for heavy work a self-acting arrangement can be used with advantage. This self-acting motion is gained by a side rod from the forked lever, acting by means of a stop-piece on another small weighted lever, at the end of which is a wrought-iron pawl, acting on a toothed wheel which is fixed to a spindle. A pinion on this spindle works in a rack beneath the table; thus, when the forked lever is in work, a lateral motion is given to the same. It is easily thrown out of motion when not wanted by moving the stop-piece. The chisel used is of solid cast steel, tapered somewhat on back and sides, which, after trial of hollow and many other forms, is undoubtedly the best for all practical purposes. It has a plain tapered end fitting into a socket. Some makers fit a 'feather' on to their chisels, with the idea of always keeping them square to the work.

This I do not recommend, as after a time the 'feather' is apt to get loose or twisted. Forked or double-mortise chisels have also been tried, but without much success. This machine is adapted for doing any kind of mortising in soft or hard woods; in the latter, however, it is necessary a hole should be bored in the line of mortise to clear the chisel. It can be worked by unskilled labour, hence its great practical value in the Colonies as well as at home. In fixing the chisel to commence work, press it up in its socket; making a light indentation in wood, reverse chisel, and bring same down again, and note that it falls square between gauge-lines. In wedging a mortise, it is only necessary to raise one end of wood and make the wedge cut before removing same. To take the jar off the cross-head at the top of vertical spindle (which is con siderable in hard wood) an india-rubber washer about an inch in thickness is fitted on spindle immediately beneath it. The boring motion needs no explanation, it consisting merely of a pair of bevel wheels worked by a handle which gives a rotary motion to the spindle, and an auger is inserted in the spindle socket in place of a chisel. The tenoning arrangement consists of a pair of adjustable bevelled knives, fixed to a forked tool-holder, fitted into the chisel socket, and working in a slide fixed to the table.

The operation is the same as for mortising; the wood, however, is cut away on the edges, and the tenon is left in the centre. Tenons can be cut rapidly in this manner, but great care is necessary to keep the knives in order, as they are, even with careful management, apt to spring, thus cutting an untrue tenon, thicker at the bottom than at top. When mortises or tenons have to be cut or holes bored at an angle, the table which holds wood can be arranged to cant and fixed to any angle desired; by means of a quadrant and pointer worked by a worm and worm wheel, it can also be made to rise and fall when the work varies very much. Some few machines worked by the foot are in use; they may answer tolerably for very light work, but for the general rough work of a builder's establishment they are of little value.

In 1861 Mr. Jackson, of Leeds, patented some improvements in the method of operating hand-lever mortising machines.

In the year 1876 Mr. John Phillips, of London, patented some improvements in hand mortising machines, the chief of which was the mounting of the hand lever at the upper end of a rocking fulcrum bar.

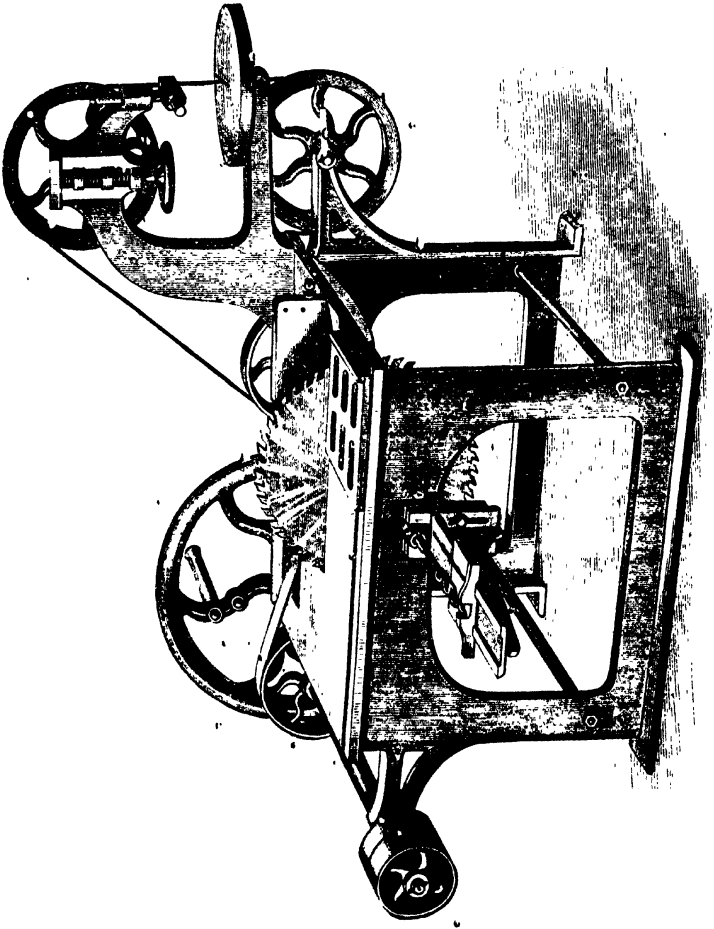


FIG. 34.—HAND OR STEAM POWER SAW BENCH AND BAND SAWING MACHINE COMBINED.

Recently also a machine has been patented with two separate vertical slides (one holding the mortise chisel and the other the core-driver), fitted to the main standard of the machine. These are worked by two separate hand-levers, attached to which are the rocking side-rods, which allow the chisel to have a greatly increased stroke, thus obviating the necessity of rising and falling the table to suit different thicknesses of stuff. The chisel has a stroke of 11 inches, and this plan should be found advantageous when mortising right through a piece of wood; but when a mortise is to be made only half-way through, the ordinary form of machine is preferable. Various minor improvements have been introduced into hand mortising machines by Haigh, G. Wilson, Green, and others. In the present year (1879) Mr. J. Phillips has patented an improved revolving tool box, especially adapted for mortising machines. The different tools employed, such as the mortise chisel, core-driver, tenoning tool, and boring bit, are fitted to the tool box in a similar manner to the nave of a wheel with four spokes. These are arranged to turn round on an axle, and are held in any desired position by means of a spring bolt. Thus after a mortise is cut the box can be revolved, and the core-driver brought into position to finish the mortise at once, obviating the constant alteration of tools or moving of wood. This arrangement is now being introduced by W. R. Reynolds and Co., London.

Hand-power saw benches with and without combinations of band sawing machines, &c., have been of late somewhat extensively introduced; and for light work and where steam is not available they are doubtlessly of considerable use. The machine herewith illustrated (fig. 34) is from the designs of Messrs. C. Powis and Co., Millwall Pier, E., who are, we believe, the original introducers of these combinations; its working is simple, and is easily understood from the engraving. The circular saw is driven by a belt from the fly-wheel shaft, to which also is fitted fast and loose pulleys to drive by steam if desired. This motion is easier and considered far preferable to the method pursued by some makers, of gearing a toothed wheel directly into a pinion on the saw spindle. The spindle is fitted in a slide, and arranged to rise and fall for the purposes of grooving, rebating, &c. One end of saw spindle is bored to receive augers.

A very useful addition to the machine is the small cross-cutting slide shown on the top of the bench. The band saw is arranged to run over three pulleys instead of two, which is an improvement, as it renders the tension on the saw much less than it would be when running over the small wheels, and the breakage of saws is considerably lessened thereby. This machine is worked directly from the spindle, and the necessary tension is given to the band saw by a spiral spring; the table is also arranged to cant to 45° for bevel-cutting. This machine should be useful to chairmakers and others who do much light irregular sawing, especially if worked by steam. An improvement in working hand-power benches has recently been introduced by Messrs. Olley, of Southwark. In consists in making the circular saw to cut up-hill against the wood instead of down. By this means the drag on the saw is very much reduced, the driving power, of course, being lessened in proportion.

Several forms of hand mitreing machines for shooting' the mitres of picture frames, &c., have been constructed, with more or less success. One of the first machines made had a motion directly vertical to the wood; this was secured by a pair of right- and left-hand knives fixed to a cast-iron block working in a vertical guide, and operated on by a lever; this gave an up-and-down or 'chopping' motion. The knives were set to an angle of 45°, but with a little alteration the angle could be varied, if desired. The knives required considerable care to enable them to cut any length of time, but some operators even now prefer this machine to others of more recent date.

Some six years since a patent for an improved mitreing machine was taken out by a Mr. Shute, of London, and we believe considerable numbers of this machine have been made. The improvement claimed is that, instead of the ordinary vertical action across the grain of the wood, the moulding to be operated on is set on edge and the knives made to cut in a diagonal direction, thus operating more or less with the grain of the wood instead of across it.

A double mitre-cutting machine has also been recently patented by Mr. Bowman, of London. In this machine two cutters are arranged in slides, working diagonally at right angles to each other; these cutter slides are worked by means of a lever and two toothed wheels, which gear into each other and into racks of corresponding pitch, which are fitted to either cutter slide. The knives are capable of cutting the moulding to a required length, and at the same time mitreing it.

Several other machines have been made, the knives being given a horizontal motion, &c., but we are afraid the machine has yet to be invented that will cut true for a continuance without splintering or leaving ragged edges—say, bolection or gilt mouldings, for instance.

There are some few machines made for fret-cutting, boring, &c., by hand or foot power, but as they are chiefly used for light ornamental work, they hardly come within the scope of this work.

CHAPTER XXVI.

CORKWOOD-WORKING MACHINERY.

The writer has recently spent a considerable amount of time in perfecting several machines for manipulating cork wood. This, owing to its elasticity and yielding properties when under the action of the cutters, is a difficult material to operate on. For rounding cork wood for bottle corks, bungs, &c., the best plan to pursue is to mount in an adjustable slide with a horizontal motion a plain steel knife some 18 inches long, which can be kept constantly sharpened by means of small revolving emery wheels bearing directly on its cutting edge. The cork wood to be rounded is secured between spring chuck centres, and when horizontal motion is given to the knife a rotary motion can be imparted to the cork wood by means of a lever and belt. The slide carrying the knife should be arranged to swivel, and be adjustable to varying sizes of corks, and also adjustable vertically at either end; thus by lowering the slide at one end and making the knife to traverse diagonally taper as well as cylindrical corks can be cut. Chucks fitted with several steel needle-points are to be preferred for general purposes, as the cork wood is very rapidly fixed in them and the slight indentations made by the steel points disappear. The chucks [illegible] different-sized [illegible]. Cork wood is often employed [illegible] for helmets, hats, socks, &c., owing [illegible] protective powers. These sheets [illegible] to be produced as thin as paper, an operation of considerable delicacy. I have employed with success for this purpose a circular revolving steel knife ground sharp at its periphery, and the cork wood, which is cut in the first instance to the shape the sheets are required, is fixed in a movable chuck-plate, arranged to revolve by hand and fitted with an extremely delicate feed-motion for bringing the cork wood to the knife, or *vice versa*.

Cork wood is largely employed in the manufacture of different kinds of floor coverings, such as corticine, &c. For this purpose it is necessary to reduce it to the very finest powder, such as would pass through a 70-mesh sieve. The production of this must be set down as perhaps the most difficult of all operations in wood conversion. If it is passed through a high-speed disintegrator, making some 3,500 revolutions per minute, the bulk of the product is far too coarse for the purposes required. Ordinary edge-runners will, with sifting, produce the required fineness of powder; but this is at the best a very slow, and therefore an expensive, process. The writer has made a variety of experiments in this direction, which have more or less failed in their object; but he is now engaged in constructing a machine in which rubbing and cutting actions are combined, and he has so far every reason to believe this arrangement will have the desired result.

CHAPTER XXVII.

MISCELLANEOUS MACHINERY FOR WORKING WOOD.

A LARGE number of machines have been produced from time to time for performing the many special operations required in the conversion of timber. Many of these machines are made for or by the users, and often embody in their construction points of great ingenuity, which the owners keep to themselves. Possibly in these days, when the rule seems to be, 'Live on other men's brains if you can, if you cannot use your own,' they may not be much to blame in not making known an idea from which, owing to more rapid and economical production, they derive an extra gain. These inventions or improvements are usually made by small masters, or men operating the machines, who, owing to slender means, are unable to pay the high rate of patent fees in vogue in this country to protect their ideas, and have perhaps found to their cost, in conjunction with many others, that the recompense arising from working for the public good may be represented by the algebraic term z. America, on the contrary, rejoices in a low patent rate, and doubtless this has its objections; but we think it may be cited as one of the several reasons why America is enabled—although affording her producers a higher rate of pay—to compete with us successfully at our very doors. In many of the machines of American construction known to the writer, although they are certainly not superior in design or workmanship to English-made machines of the same class, they seem to him to be carried further and made more complete in their general details and range of operation, small and effective 'notions' being introduced, increasing little the first cost of the machine, but adding greatly to its economic production when multiplied by a series of months or years.

Amongst miscellaneous machines for converting wood those for finishing the surface by means of sand paper are deserving of mention These vary in construction according to the nature of the work required. For finishing doors or other large surfaces usually a number of flexible arms are attached to a column or bolted by means of a bracket to a wall. By the use of elbow joints these arms are arranged to move in any direction. The sand paper is fastened on a disc which is mounted on a vertical spindle, and receives motion by belt gear. A flat surface is thus presented by the sand-paper face of the disc to the wood. The article to be finished is placed on a table immediately beneath the revolving disc, which can be adjusted to different thicknesses of work by a hand wheel and screw or other suitable means. The pressure of the disc can be regulated by a spring, and an exhaust fan should be attached for the removal of the dust, thus enabling the operator to see at a glance when the right amount of finish is attained. For straight, flat surfaces the sand paper is sometimes mounted on a cylinder or drum placed immediately below a table, but part of its periphery projecting slightly above its surface. The wood can either be passed over the face of the drum by hand or a self-acting roller feed can be fitted, similar to that on a light planing machine. The face of the drum on which the sand paper is fixed should be covered with some moderately flexible material, and the drum should be adjustable vertically to vary the amount of the cutting action of the sand paper.

For turning broom handles and such like cylindrical rods several machines are in use, varying chiefly in the arrangement and shape of their cutting tools. For rounding purposes a hollow mandrel is usually employed, into which hollow chucks arranged with knives are fitted; these chucks vary in their bore according to the sizes required. The wood to be rounded is either pushed through the chuck and mandrel by hand or by the aid of self-acting feeding gear. One patented by Messrs. C. B. Rogers and Co., of Norwich, U.S.A., and shown at the International Exhibition in Paris, 1878, is somewhat novel. It is self-feeding, but does away entirely with feeding gear, the cutters being arranged in the hollow mandrel through which the wood passes in such a manner that a kind of screw feed is given, which, after the cutters first strike the wood, pulls it through without extraneous aid. The mandrel is speeded to make 3,000 revolutions per minute.

A very ingenious machine for turning oars was invented and patented by one Ezekiel Page, an American, in the year 1842, by which he was enabled to shape two oars out of a piece of wood where one only before had been obtained, the remainder being cut to waste. Our space, however, unfortunately forbids an extended notice. About the year 1855 a machine for dressing oars on Steele's patent was erected at the Royal

Dockyard at Chatham. The wood was first roughed out by two sets of circular saws mounted upon swivelling cylinders, arranged to turn on their centres, whilst a sliding bed allowed them to advance or retire from each other by the action of an adjustable 'feeler bar' or tracer. After the wood passed through this machine it had the general outline of an oar, but with rectangular section; it was then passed to a finishing machine, when the loom and blade were finished simultaneously by two sets of cutters.

Mr. G. L. Molesworth, in his paper read in 1857 before the Institute of Civil Engineers, mentions several machines for sawing curved ship's timbers, including one invented by a Mr. Hamilton, of the United States, and another by M. Normand, of Havre. In Mr. Hamilton's machine two straight saw-blades were attached to buckles arranged to turn on their centres whilst in motion. These saws were mounted in swing frames formed of hollow wrought-iron bars, to combine strength with lightness. In one large or external swing frame two internal swing frames were arranged, with a transverse sliding motion along the external swing frame. Each of the saws which were mounted in the internal swing frames were turned on their centres, and guided by the workman to any line marked out on the timber by a forked lever of wood applied to the back of the saw. The timber was arranged to swivel on its axis by means of gearing, thus enabling a variable bevel to be cut as it was fed forward.

A method for ensuring accuracy in sawing ship's timbers of varying bevel, obviating the necessity of trusting entirely to the eye of the workman, is worthy of notice; it was invented by a Mr. Green some five-and-twenty years ago. The machine was fitted with a small roller, worked by suitable gearing, and the travel of its periphery was made proportional to the feed of the timber through the saws. A tracer was attached by gearing to the swivelling centre of the log, and indicated any bevel given to the wood. A small diagram of the required bevel was drawn to scale and wound round the roller; the tracer was kept on the lines of the diagram as it slowly revolved by means of a screw, and the log was cut to a bevel corresponding with the diagram.

The novelty in M. Normand's machine for cutting ship's timbers consisted in the method employed for supporting and feeding the timber. The log rested on four horizontal rollers, which were capable of moving in the same plane, so that their axes may be either parallel or in such a position that the imaginary lines formed by the production of their axes shall meet at the centre and be portions of radii of a circle of large or small diameter, as required. By means of a handle the positions of these rollers could be altered, and the log caused to travel through any segment of a circle, the centre of which was indicated by the roller axes; and as this centre could be altered whilst the machine was in motion, the curve described to could be varied to any extent. A frame, upon which the rollers were supported, was arranged on a longitudinal axis, so as to be canted with the rollers and the log to any desired angle. A ratchet movement was added, to make this movement self-acting if required.

Amongst other machines mentioned in this interesting paper was a simple one for rounding wood for broom handles, &c. This was the invention of a

Mr. Wilson. In this machine a cylindrical gauge cutter and a paring tool in the form of a disc were employed. They were arranged to turn in their sockets as required, thus presenting continually a new cutting edge.

In 1868 Mr. J. Sanders, of New York, patented a somewhat novel combination of circular saws and cutters for mitreing the joints of rectangular frames, such as are used in looking-glasses, pictures, and window frames. At either end of a spindle, which revolved in bearings fixed at the top of an iron frame or table, was mounted an annular circular saw. These saws were not mounted in the usual way, but secured to turned wrought-iron flanges or washers. These flanges were bolted to hollow circular cutter-blocks, which were fitted with three or more plane irons, arranged to project slightly beyond the surface of the saw plate and plane the joint of the mitre smooth after it was cut by the circular saw. These plane irons were fixed in recesses in the circular cutting block at an angle of about 45 degrees to the face of the plate, and kept in their places by means of wedges actuated by screws. This plan leaves a clear space for the discharge of shavings, &c. The wood to be jointed is placed on the frame, sliding horizontally on the top of the table, and fitted with fences at an angle of 90 degrees to the face of the saw. This sliding frame is fitted with stop pieces and index plate, by which the lengths of the frames to be jointed can easily be regulated. The sliding plate works longitudinally on V's, and can either be pushed past the saws and cutters by hand or self-acted by means of a rack and pinion actuated by worm gearing fixed on a countershaft at one end of the machine.

In 1853 Mr. W. Kendall, of Blawith, Lancashire, took out a patent for improvements in machinery for turning and hollowing wooden boxes, or cutting out solid wood into boxes or other receptacles of a like class. The apparatus consisted in general form of a horizontal spindle, carrying a species of chuck, which was fitted with a projecting circular gauge of the size of the outside of the box to be hollowed. In the centre of the chuck and gauge was a cutter made up of a small tool, fitted into a second revolving chuck in such a way as to permit a small portion only of the cutting edge to project. The wood blank is turned in a separate lathe. This blank is placed with its axis coincident with the axis of the cutter spindle; it is urged longitudinally forward by a runner its end being inserted in the gauge, whilst the revolving cutter scoops out the wood. The cutter and its position as regards the centre of revolution were so arranged as to cut the hollow to the required gauge of box.

Amongst miscellaneous wood-working machines must be mentioned Messrs. Greenwood and Batley's machines for manufacturing gun stocks and other warlike materials. Several series of these machines have been erected by them for the Government at Woolwich, Enfield, and elsewhere, leaving little in the manufacture of a gun stock to be performed by hand, the recess for receiving the lock even being cut out by mechanical means. This operation is novel and somewhat difficult to perform. A series of five cutters are mounted on five separate spindles, each fitted in a separate slide arranged in a rotating circular frame. Each slide has a vertical and horizontal movement. The gun stock and a hardened steel model of the recess required to be cut are fixed on a table sliding horizontally at right angles to the horizontal motion of the cutter slides. The cutter spindles run at a high speed, and are brought into operation in succession, and by compounding the motions any shaped recess can be accurately formed, each cutter being governed by a 'tracer,' which travels over the surface of the required model.

CHAPTER XXVIII.

MISCELLANEOUS MACHINERY FOR WORKING WOOD—*continued.*

SEVERAL attempts have been made to supersede manual labour in felling trees in the forest, but, owing to the difficulties of situation or manipulation, hitherto with only qualified success; and although possibly under special circumstances mechanical means may be employed economically, we are of opinion that the day is far distant when the sound of the woodman's axe will be banished by steam machinery. Inventors in this direction include Thompson, Fousèque and Cordes, Ransome, and others. Thompson exhibited an apparatus for this purpose as far back as our International Exhibition of 1862. This consisted of a couple of saws let into an endless band reciprocating between two pulleys. One pulley was fixed on either side of the tree to be felled, and one of them was arranged to pivot in a circular segmental slide concentric with the stationary pulley. The saw was fed into the tree by shifting the saw frame towards it radially upon the fixed pulley as a centre; after the tree was cut half-way through the saw was moved to the other side and the operation repeated.

A few years since Messrs. Ransome and Co., of

London, patented a machine for felling and cross-cutting trees. This machine briefly consists of a steam cylinder of small diameter, but arranged with a long stroke. This cylinder is mounted on a wrought-iron frame, and arranged to pivot by means of a hand wheel and worm, gearing into a toothed quadrant fitted to the back of the cylinder. The saw is fixed directly on to the end of the piston rod, and arranged to travel in guides; the teeth of the saw are formed to cut only during the backward stroke. The cylinder is supplied with steam from a portable boiler by means of flexible tubing, and the machine, when used for felling, is attached by a screw to a trident-pointed bar driven into the tree itself. After the saw has progressed some little way in its cut wedges are driven into it, to prevent the saw being pinched or buckled and to guide the fall of the tree. Four men are required to manipulate.

Another method of felling trees by means of revolving cutters has recently been tried, but without much success. The plan pursued was to mount in a frame a lever carrying two arms, which were adjustable horizontally to the size of the tree. On these arms were mounted revolving cutters, which made an incision into either side of the tree; to keep the machine taut a chain actuated by a winch was attached to the frame and encircled the tree.

A portable tree-feller and sawing machine was patented by W. H. Smyth in 1878. It consisted of a reciprocating saw, united by a connecting-rod with a cross head, working on guides. The guides are loosely united at their rear end with the driving axle, so that they move round it as a centre as the saw makes its cut. The driving crank is formed in this axle between the guides, and is connected with the connecting-rod. A lug on the latter actuates a paul gearing with a ratchet on the end of a spindle, to the other end of which is fixed a pinion gearing with a rack formed on the frame at the upper end of the machine, so that at each stroke the saw is fed forward into the cut.

In 1874 also Fouseque and Cordes, of Paris, patented an apparatus for cutting down trees.

An antifriction or rolling cam-press for extracting the stumps of trees, the invention of Mr. Dicks, an American, should be mentioned; although it has never come into much use, it was of great strength, and possessed several features of novelty and interest to engineers.

During the erection of our International Exhibition of 1851 a series of machines were designed by Paxton, Birch, Furness, and Cooper for cutting gutters, shaping hand rails, sash bars, &c., and sawing, planing, and moulding the various wood work used in the erection.

A considerable number of patents have been obtained in connection with carving machinery. Mr. J. Gibbs obtained one in 1829 for a machine for shaping and recessing in low relief, shaping busts, &c. Irving's patent in 1843 consists chiefly of improvements and modifications of Gibbs's, but he claims all combinations for carving in which the swing frame carrying the cutters and table carrying the wood have both circular motions.

Jordan's well-known system of carving machinery by means of revolving tools was patented in 1845. It was extremely ingenious and novel in many of its working details, but, being somewhat complex and elaborate, has never come into extended use. Some ten years after a carving machine was invented by M. Mathieu, a French engineer. It was made up of four motions, consisting of the direct rotary action of cutters, a traverse motion, and a transverse motion of cutters and a raising and lowering action of the wood or other material under treatment.

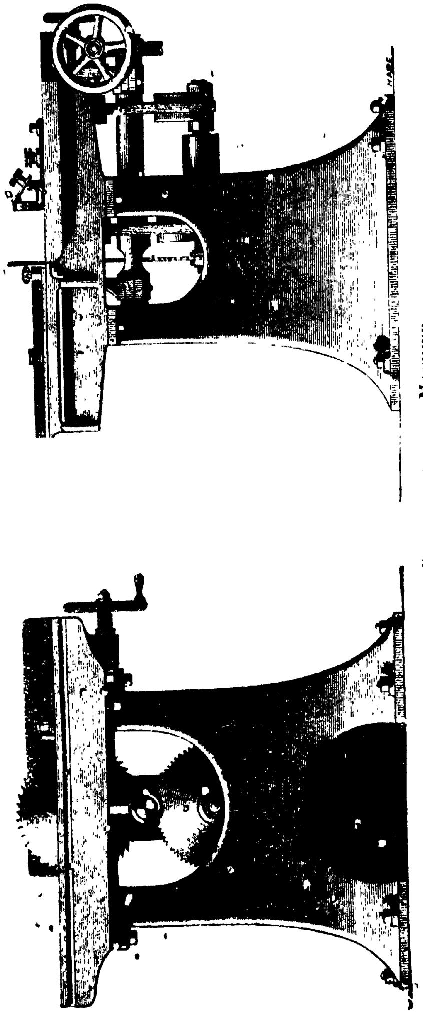
A number of machines have been designed for the manufacture of wood interiors of railway carriage wheels. Complete sets of machines for this purpose have been erected by Messrs. Greenwood and Batley, Robinson, &c.

Messrs. Greenwood and Batley's series of machines includes an upright circular-table planing machine for planing the blocks of wood for the interior of the wheels before being jointed into tabs. This machine was arranged with a horizontal rotating table, fitted with dogs for holding six blocks of wood. On each side of this table is a standard carrying a slide with headstock and vertical spindle; the lower end of this spindle is fitted with a rotating arm and cutters, similar to a Bramah planing machine. The table is made to rotate slowly, and each block of wood is brought in succession under one of the cutter arms, which surfaces it on the upper side; the block is then reversed and again passed under the cutters; it is thus planed to an accurate thickness The cutter heads are made adjustable to varying thicknesses of wood. In another machine the operations of sawing, tenoning, and adzing the blocks are combined. The blocks or tabs are sawn to the outside diameter by means of a band saw. Ten tabs are held in a horizontal rotating table, which, as it rotates, brings the outer edge of the tab in contact with the saw. The saw is arranged with vertical, lateral, and canting adjustments to cut the tab to the required diameter and bevel. In the interior of the before-mentioned table a jigger or reciprocating fret-saw works and cuts the inner edge of the tab to the required diameter of the nave boss of the wheel. The table continuing to rotate slowly, the periphery of each tab, after being sawn, is brought under the operation of a pair of cutters mounted on two adjustable spindles working horizontally, which rebate the tab on either side. Following this, the periphery of the tab is operated on by planing cutters mounted on a vertical spindle which smoothes the sawn surface, and another cutter mounted on a vertical spindle chamfers off the interior edge of the tab to fit the corner piece left between the flange and the boss of the nave. As each tab is finished it is replaced by another.

In Messrs. Robinson's machines for making 'Mansel's patent wheels' the blocks of wood are edged and divided on a circular saw bench with two adjustable fences, which can be placed at any desired angle to each other; these are arranged on a dovetail slide, which is carried through the saw by a screw and bevel gear with quick return motion, and is so arranged that it is automatically thrown out of gear as each block has passed the saw. Another machine of this series is arranged to bore out the centre of the wheel to receive the boss. The main boring spindle is fitted with a screw, which, in addition to bringing the spindle down to its work, is used for forcing the boss of the wheel into the centre. The circular table is made to revolve horizontally, and fitted with a catch which divides accurately each revolution of the table into as many parts as there are holes required for bolts to secure the boss of the wheel in its place. These holes are bored by a supplementary spindle.

A number of machines for cutting match splints have been made, including one patented by John Long, of Glasgow, in 1865. The improvements herein contained relate to an arrangement and combination of certain parts of mechanism, and have for their essential object the cutting or dividing of timber with rapidity into small pieces, such as those used in the manufacture of lucifer matches, pencils, or other generally similar purposes. The apparatus consists of a strong iron frame, in the lower portion of which the main shaft revolves by means of a belt actuating a pulley fixed thereon. At one end of the shaft a fly wheel is fixed, at the other end a crank or cam is attached, and a connecting rod extended from this to the movable block or frame carrying the knife or knives by which the vertical cut in the wood to be divided is made. As the cam or crank revolves, its eccentric or circular motion is converted by means of the connecting rod into a vertical reciprocating motion of the knife or knives. On the top of the framework V or other shaped slides are fixed, and on these travel the saddle or table carrying the pieces or blocks of timber to be divided. The table is furnished with two gutters above, into which the blocks of timber previously cut to the required shape are placed. The table is caused to travel horizontally on the slides, and thus the faces of the two blocks being cut are alternately brought in front of the knife or knives. The horizontal movement is imparted to the table by means of a cam fixed into the main shaft. The cam is grooved, and into this groove enters an antifrictional roller on a stud projecting from the side of a strong lever. Therefore as the cam revolves the lever is caused to vibrate; and its upper end being coupled to the saddle or table, the two blocks of wood impart the necessary horizontal motion to it. Attached to that portion of the framework in which the vertically acting knife or knives are located is a projecting set or sets of knives, which cut into the blocks of wood as they alternately travel before them. By these means the wood is first divided into a number of horizontal strips, needing only the downward motion of the knife to separate them in the form of rectangular bars from the block or blocks of timber. The splints are thus at once produced in a state fit to be used for any purpose before described. As soon as one downward cut has been made, the table travels back to its former position, and the other block is similarly treated. It should be mentioned that the table is fitted with two sets of forwarding gear, by means of which, as soon as one set of splints have been cut off the block of wood, it is forced on a distance sufficient to allow an equivalent portion to be divided or cut off for the next set of splints.

Our illustrations (figs. 35 and 36) represent a machine designed by Messrs. Richards and Atkinson, of Manchester, for sawing to exact finished dimensions. For this purpose especial care has been taken to ensure the utmost accuracy in the working details. As will be seen from the drawing, two saws are mounted in a swinging frame, either of which can readily be brought into use by the worm gearing for ripping, cross-cutting, or grooving, as may be desired. The driving band is so arranged that it retains its proper driving tension at any position of the saws. For cutting out printer's reglets, accurate pattern, or other similar work this machine should be of considerable service.



FIGS. 35 AND 36.—DIMENSION SAWING MACHINE.

Our space precludes our noticing the various improvements introduced into ordinary lathes for turning wood, but we herewith illustrate one (fig. 37) designed for copying special and fixed works by F. Arbey, of Paris. It is constructed for cutting twisted or straight flutings, and other ornamental work usually found in various kinds of furniture, such as the beads and flutes in table legs and columns. Although the patterns it is capable of copying appear somewhat complex, the action of the machine is positive; but it can be altered and varied very considerably. The speed of the cutters is adjustable to suit different kinds of work, and the designs are readily altered. Altogether it must be held to be a very fair example of its class.

CHAPTER XXIX.

MOTIVE POWER FOR DRIVING WOOD-WORKING MACHINERY.

THE earliest motive power used for driving wood-working machinery was that produced by the water-wheel and wind-mill. The latter has entirely fallen into disuse; but a great number of water-wheels are still in operation, and, where sufficient water can be obtained, it is undoubtedly the most economical power available. Turbines and other forms of water engines have of late years been introduced, with more or less success; but, as a sufficient fall or head of water is seldom to be had, steam must of necessity be the power most generally employed. The different types of engines are 'as thick as leaves in Vallambrosa;' and when a user is confronted with six-cylinder, three-cylinder, rotary, oscillating, &c. &c., all warranted to effect wonderful results, no wonder he finds 'confusion worse confounded.' From a somewhat extended experience the writer is of opinion that for driving wood-working machinery, except under certain special conditions, the most economical and convenient form of engine is the horizontal high-pressure, fitted with a condenser, as by this means a vacuum is formed behind the piston, relieving it of back pressure and giving an increase of power and a consequent saving in fuel. We will not here dwell on the extremely short-sighted policy of employing an engine of a low class. This has been urged over and over again; but, tempted by a low first cost, numbers of people may still be found to purchase these miserable productions, which have already considerably damaged the high character for design, materials, and workmanship once held by English-made engines in all parts of the world. So much having been done in that direction, it would be out of our province to write at length on the economy of the steam engine; but we take it that an engine for this class of work, to be really economical, should combine in its construction the following points:—(1) a stroke of at least twice the diameter of the cylinder; (2) an efficient condenser; (3) an automatic expansion slide, controlled by sensitive governor gear; (4) a steam-jacketed and lagged cylinder; (5) short steam-ways; (6) all bearing surfaces well fitted and lubricated, and an efficient method of packing; (7) large cylinder area for nominal horse-power; (8) fly wheel of large diameter and extra-heavy section. In addition to these points, as the duty of an engine for saw-mill purposes is often very severe, great care should be taken that the materials and workmanship employed are of the first class. The crank shaft, connecting rods, &c., should be made of the best fagoted scrap-iron; the piston rod, keys, pins, &c., of steel; the bolts, joints, &c., subject to any special wear should be case-hardened. All glands should be bushed with gun metal, and the guide blocks and crank-shaft bearings made adjustable for wear.

If power has to be transmitted a considerable distance by means of shafting, a large amount of force is lost through the friction necessarily engendered; and it has become more or less the fashion to substitute several smaller engines and boilers in lieu of one large one. This plan has the additional advantage that, should an accident occur, the whole establishment is not necessarily laid idle. If small high-speed engines are employed, the momentum of the reciprocating parts should be balanced. This can be done by so counterweighting the crank that the piston, when working, moves in an opposite direction to the counterweights. The shaft is thus relieved from excessive shock.

In these engines, which should work expansively, the bearing surfaces must be of longer area than in slower running engines, and the workmanship must be of the first order, or they will be found to deteriorate rapidly.

In small establishments, where much power is not required or where space is of great value, vertical combined engines and boilers are often employed. The foregoing remarks apply with equal force to these as well as any other form of engine that may be used. In vertical combined engines and boilers all working parts of the engine should be made totally independent of the boiler, as the constant action of the engine produces an injurious strain on the boiler, and, from the expansion and contraction of the boiler, the proper working of the valves of the engine is also interfered with. As regards the construction of the boiler, we recommend the dome description with cross tubes in preference to the multitubular form, as being easier kept in repair and free from deposit. The cross tubes should be made of Lowmoor or equal brand of iron, and so arranged that the flame should be distributed and as much heat as possible extracted from it before being allowed to pass into the chimney.

The types of steam boilers at present in use are almost endless. Although the locomotive and other forms doubtless possess advantages under certain conditions for saw-mill purposes, all things considered, the Galloway type of boiler, or the Cornish boiler with cross tubes, is to be recommended for safety, durability, and economy; and they have also the additional advantage of being readily cleaned and repaired, and are easily managed, which is important, as in saw mills, especially in remote districts, skilled labour is not always obtainable.

In recent types of Galloway boilers several improvements of some moment in their shape and mode of manufacture have been introduced. The edges of the plates are planed, by which means any flaws in the iron are easily detected. The diagonal edges of the plates are afterwards 'fullered' with a flat fullering tool which brings the plates close and tight together. The plates are riveted by a dead pressure, and not a sudden blow, the pressure being adjusted according to the gauge of rivets and plates. If a Cornish boiler is employed, it should undoubtedly be fitted with coned cross-tubes, the circulation of the water being much improved and the strain on the joints from unequal expansion considerably lessened.

An advantage in the Galloway type of boiler over the Cornish is that, without complicating the form of the boiler for cleaning or repairs, the heating surface is much greater, the tubes being in the direct passage of the heat which strikes against them. The cone tubes are usually constructed of plates of a thinner gauge than the rest of the boiler, thus enabling the heat to pass more readily into the water. The boiler plates should be carefully selected, and the edges of the plates planed; the rivet holes should by preference be drilled instead of punched, as the strength of the boiler is thereby considerably increased. Should the rivet holes be punched, they should be of an even pitch, thus equalising the strain on the rivets. The size and pitch of the rivets should be accurately proportioned to the thickness of the boiler plates used. The resistance of the boiler shell to bursting pressure, and the flues to collapse, should also be carefully studied.

As regards the prevention of incrustation, great care should be exercised in using anti-incrustation remedies, as many of them contain either acid, which affects injuriously the boiler plates, or some greasy or glutinous matter, which gives them a tendency to burn. Grease especially should never be introduced into a boiler. We have found that by blowing out once a fortnight, and using a solution of common soda, we have had little difficulty in keeping a double-flued Cornish boiler clean, although the water used was an indifferent sample. In waters containing much sulphate of lime or other deleterous substances a simple form of feed-heater should be employed, as by its use the water is considerably purified before entering the boiler, and any deposit of incrustation can more easily be removed. Many remedies for incrustation have been introduced, including pieces of oak suspended in the boiler, oak or mahogany sawdust, branches or sprays of the trees, spent tanner's bark, chloride of tin, muriate of ammonia, &c.; but it may safely be concluded that although a remedy may answer in one sample of water, it by no means follows that it may be equally successful in another, as much undoubtedly depends on the nature of the calcareous salts contained in the water employed. Hydrate of soda has been used with considerable success in waters containing silicates and some kinds of salts, and boracic acid is also used in the prevention of deposits. Of late years so great has been the desire to produce something new in the means employed for generating steam, that what Fairbairn calls the very essence of constructive science is often neglected, and the distribution of the material and form best calculated to ensure the maximum strength with the minimum amount of complication is almost entirely lost sight of. Boilers used for driving wood-working machinery should be constructed with one-third larger fire-grate surface than is usual for burning sawdust and waste wood as well as coal. The combustion of wood and coal together produces a heat of considerable intensity. Care should therefore be taken that the flame of the fire should be equalised and distributed as much as possible, that the flues should be of simple construction and easily accessible. In some districts also the water available is heavily charged with carbonate of lime or other substances which very readily cause incrustation, and, unless great care is exercised, the multitubular or other complicated form of boiler is rapidly destroyed. The boiler employed should in all cases be of ample power for the work to be performed. An apparatus for heating the feed water by the exhaust steam should also be fitted to the boiler, as by this small additional outlay a saving in fuel of at least 10 per cent. is effected.

Much has been written on the corrosion of steam boilers and the best means to employ for the prevention of the same. External corrosion or oxidation is due to atmospheric influences, or damp foundation of the boiler, and is usually easily prevented by covering the boiler with felt or a suitable material which prevents also radiation of the heat. If the boiler is fixed in a very wet situation, in addition to the felt it is sometimes found necessary to case the boilers with sheet lead. Some classes of paint also prevent oxidation in a very considerable degree. As regards internal corrosion, very great difficulty is often experienced, especially with certain samples of water, and where tubular or any complicated form of boilers are employed in keeping the same in a satisfactory working condition. This is most generally felt in marine boilers, sea water being a very active corrosive agent. It is generally held that, owing to the varying densities of the metal of the rivets and the boiler plates, a mild galvanic action is produced, and corrosion usually commences round the rivet holes. Corrosion thus especially attacking the rivet joints is attributed by Mr. William Kirtley[1] to a mechanical action combined with a chemical action, and, from his experience, in locomotive boilers constructed with lap joints it attacked the smoke-box end of the boiler, but sometimes extended slightly in an irregular manner over the whole boiler surface.

The mechanical action referred to is attributed by Mr. Kirtley to the continued expansion and contraction of the boiler springing and bending the plates at the joint lines, thus breaking off the scale deposited by the water—which is found to be in a certain degree a protection against corrosion—and leaving the boiler plates

[1] *Proceedings I. M. E.*, 1866.

exposed to the continual corroding action of the water. Owing to the high pressure at which locomotive boilers work as compared with stationary boilers, this springing action would without doubt be more severely felt in boilers of that type; consequently the tendency to corrosion from this cause would be greater. It is also found that this detrimental action is increased when frame stays or brackets offering a special resistance to the expansion of the boiler are used. To obviate as far as possible the excessive corrosion at the rivet joints, a plan often pursued is to roll the iron plates with gradually thickened edges, which distributes the springing action over a considerable area. Welded joints seem also to exercise a tendency to prevent corrosion by removing the especial strains found in using lap-welded joints.

Should more than 25 horse-power be required, it is preferable to use a pair of boilers instead of one.

All Cornish boilers above 12 horse-power should be constructed with double flues, and fitted with Cross or Galloway tubes, and should in addition be thoroughly stayed. It is a trite but not unnecessary remark in these days of unfair trading and excessive competition that when human life is at stake only a first-rate quality of iron should be used in the construction of steam boilers, and where the action of the fire comes in direct contact with the plates, iron of the very highest possible quality only should be used For forest use, or where machinery has to be moved from place to place, the ordinary portable engine and boiler on wheels is to be preferred. The different forms of three-cylinder engines, such as the Brotherhood,' Willans', &c., although using a considerable amount of steam, are sometimes found useful in driving single machines. Where the rate of speed is not too high they are often fixed directly on to the main spindle. In the recent (1878) International Exhibition in Paris we saw attached directly to the bottom saw-wheel spindle of a band sawing machine, exhibited by Mons. J. Fau, of Bordeaux, a new form of rotative engine, patented by P. Martin. It was capable of running at a very high rate of speed, but as to its advantages or the reverse we are not in a position to speak.

Great care should be exercised in setting the boiler, and the draught should in all cases be regulated by an automatic steam-damper, which, as it requires no attention and is regular in its action, effects a considerable saving over the old form of slide damper, the working of which is oftentimes neglected by the fireman. It may not here be out of place to remark on the false economy of employing so-called 'cheap' labour in the management of engines and boilers, as it has been proved beyond doubt that an intelligent trained man, who has some knowledge of the properties of steam, who knows the economy of keeping a bright even fire and his boiler, safety valves, gauges, &c., clean and in good condition, will, in the course of twelve months, get extra duty out of his engine, and effect a saving in fuel and repairs very much in excess of the extra wages paid him. The explosions which almost daily occur, occasioning great loss of life and destruction of property, are generally attributed to either the culpable ignorance of the attendant or to the use of worn-out or badly constructed boilers. The subject of granting certificates to engine-drivers and placing steam boilers under Government inspection has of late years been moved in the House of Commons on several occasions, and although, doubtless, a moderate Act would be for the general public good, the question seems to have been, at any rate for the present, quietly shelved.

The boiler and all steam pipes should be covered with felt or other non-conducting composition, to prevent radiation of heat or freezing. The composition known as Leroy's gives for this purpose satisfactory results, but we hear highly spoken of a later introduction, known as Toope's patent. This covering is composed of hair, felting, and paper, which is protected from charring by an interior lining of asbestos. It is said to be an admirable non-conductor, has absolute freedom from cracking, is light and easily fixed or removed, and is indestructible at any temperature at which steam is used. If it is found to fulfil all these conditions, it will, without doubt, be of great value to steam-users, as it overcomes several objections to most of the boiler coverings now in use, not the least of which is that it is entirely free from the crumbling action now so often found.

Before concluding our remarks under this heading we should wish to draw our readers' attention to the great practical value of the mineral asbestos for packing steam piston and pump rods, stuffing boxes, &c., and when combined with felt it is an excellent covering for steam boilers. Although its existence has been known for many centuries, it is only during the last few years that its valuable properties have been utilised. Asbestos of the best quality is found in considerable quantities in the Italian Alps; it is fibrous in texture, and is capable of being woven or combined with other material. It also possesses the peculiar property of being unaffected by the action of fire, acids, friction, or moisture. It can also be used in the form of paste or millboard for steam and other joints. It is also very well adapted for packing steam fittings, such as cocks and water gauges, and we can, from our experience, speak in favour of its valuable qualities. Compressed wood pulp made up in the form of annular rings for glands, and sheets and washers for steam joints, has several features to recommend it, notably that the joints are easily broken and renewed, that the pulp readily retains the lubricating matter employed, and is anti-corrosive and will stand superheated steam. For glands the packing is usually made in segments of the exact size of the stuffing box.

CHAPTER XXX.

ARRANGEMENT OF SAW MILLS AND ECONOMICAL CONVERSION OF TIMBER.

A SAW MILL being for the purpose of converting crude material into articles of commerce and general utility, the great point to be aimed at is how to accomplish this with the greatest economy and despatch combined with quality of production. Saw mills being often situated in crowded cities, where space is of great value, and where any kind of building has to do duty, a set plan for laying out or designing a mill can hardly be laid down, but must vary according to circumstances. The following hints, however, may not be out of place:—

Where space is obtainable, buildings should be arranged with large sliding doors at either end of the mill, so that timber may be passed in at one end in the rough, and, after being worked through the various machines, passed out at the other as manufactured goods. A tramway should run down the centre of the mill, and where much heavy timber is worked an overhead traveller is necessary. In arranging a mill advantage should always be taken of the site with reference to land or water carriage of the timber. If near a canal or river, the mill should be so arranged that as the timber left the water it should pass directly to the heavy machines, such as timber frames or rack benches for breaking down; its further manipulation is thus at once made easier. As regards the best shape for a mill, where all ordinary classes of work, such as sawing, planing, moulding, &c., are performed we have found a rectangular building of a length of about two and a half times its width the most suitable shape.

If an engine and boiler is used to give the motive power, it should, if possible, be placed outside the main building. If placed inside the builing, it should be divided off from the rest of the machines. The whole of the main shafting should be arranged underground and run transversely across the building; it should be easily get-at-able for lubrication, removal of belts, &c. Underground chambers should also be provided for the reception of sawdust and shavings.

If the building is more than 100 feet long, three lines of shafting should be used, the last two shafts of which can be arranged to run at higher speeds if required. We have found a speed of about 250 revolutions per minute the most suitable for all ordinary wood-working operations. The various machines should never be crowded together, and if upper floors are used light machines with, if possible, a rotary motion should be fixed on them, as the constant vibration from some machines with a reciprocating motion has a tendency to damage and displace the joists and brick-work unless of very strong section. The shafting for an upper floor should be fixed at the roof of the ground floor. Adequate means for hoisting timber to this floor must be taken. A first-rate and rapid plan for carrying up deals is to arrange an endless belt, some 9 inches wide and fitted with stop pieces, to run at an angle of about 45 degrees from the basement through a trap door to the floor above; by this means deals, &c., can be carried up as fast as they can be placed on the belt.

With the object of facilitating the conveyance of timber from on board ships, barges, or railway trucks directly to the various machines to be converted, or to the yard to be stacked, without the aid of manual labour, Mr. Samuel Boulton, of London, in the year 1868 took out letters patent. For this purpose the inventor proposed to construct in the timber yard and saw mill channels, conduits, shoots, troughs, or pipes containing water, either open or closed, and either sunk in the ground, laid upon or raised above it; these channels to lead from the water-side or other locality; the timber to be conveyed into such water channels from the vessel by means of endless chains or bands provided with dogs.

When the timber reaches the water channels, it can either be pushed along or conveyed by an established water current. Mr. Boulton decribes an elaborate arrangement of water channels, &c., designed to carry timber to any part of an establishment; but when we consider the numerous drawbacks to the scheme—the discoloration, increased risk of cracking in the drying, the extra power required in sawing wet timber, &c.—we are afraid it cannot be held to be of much practical value, at any rate in this country.

All saw-mill floors, whether ground or otherwise, should be made of ample strength to withstand machine vibration or any load that may be placed on them. The ground floor should be built on piers, and we have found joist floors the best form of flooring to use, as from their construction they resist successfully any excessive vibration. Where a single first floor is used and the bearing exceeds 10 feet, herring-bone strutting should be used.

As regards the most economical coal for the production of steam much has been written. Of course the heat evolved from the combustion of different samples of coal, differs very considerably, the carbon varying from 75° to 05°. We prefer, on the whole, some samples of South Wales steam coal we have used to any other.

Sawdust and wood refuse, if mixed with a little tar or bituminous coal, makes a very fierce fire, but should be used with care, or burnt boiler-plates will be the result.

Owing to the daily increasing competition in the conversion of wood from Norway, Sweden, and even America, who export largely to this country manufactured joinery of all kinds, English makers have at present, and will in the future have greater, difficulty in successfully holding their own. The success of this competition in the case of Norway and Sweden must be attributed to the abundance of the crude material and the cheapness of labour. This is otherwise as regards America, as, although timber is cheaper, wages are considerably higher. This can in a measure be explained by the much greater facilities offered in America to inventors to protect even the smallest improvement in the constructional details of labour-saving machinery. In this country, on the contrary, owing to the high cost of letters patent, a workman has no incentive to improve the smaller details of a machine, which tend so much to its productive efficiency, and, unless an idea is strikingly original, invention does not pay. In fact, in England brains often have to seek money to carry out their ideas, whilst in America money seeks the brains. This, however, by the way.

Supposing the mill to be ready for receiving the machinery, and the particular branch of wood conversion or manufacture decided on, the next and very important step is to obtain that machinery which is best and more especially suited to execute with rapidity and economy the work required. The selection of the requisite machinery is a matter of the highest importance, and, unless very judiciously undertaken, an investor may find himself saddled with a lot of costly and elaborate machinery ill adapted to his wants.

Care should be taken that the machinery selected should combine high-class workmanship and material, the greatest amount of productive efficiency with the least amount of complication. The so-called 'cheap' machinery must be held to be dear at any price, the difference in first cost being rapidly counterbalanced by constant breakdowns and loss of time, often coupled with inferior work. The price of a really high-class, labour-saving machine should always be a secondary consideration.

When the necessary machinery is arranged, the very important question of how to employ it economically and profitably presents itself. As regards the labour employed in directing the conversion of wood by machinery, the highly skilled and highly paid workman is as a rule the cheapest, the first difference in cost being soon counterbalanced by an increased output from the machine and of better average quality Where a steady and uniform business of a certain class is carried on, we are strongly in favour of piece work. Much has been written for and against this system, but as far as our experience extends a man is rarely or never found who will perform the same amount of work whilst working by the day or hour as he will whilst on piece work. Piece work, which, by the way, should never be carried to excess, also encourages diligence and energy, and the skilful workman thereby reaps in wages his just value. Of course in some high classes of work it is very difficult to introduce piece work with advantage, but for the vast majority of wood manufactures it is undoubtedly the true system.

Of course in piece work workmen have the greatest interest in completing work with all possible speed. Care must therefore be taken that it is not allowed to be 'scamped,' and on no account should the quality of the finish and detail be sacrificed to quantity of output. Piece work has also the additional advantage of offering a premium to the operator, of keeping his machine and tools in constant use and in the highest state of efficiency.

Care should be taken that all machines are set at a dead level both horizontally and transversely, and are free from excessive vibration when in work, and adequate means taken for transporting rapidly and with little manual labour the required timber. Where many saws, either circular or straight, are in use, a machine for sharpening should invariably be employed.

The wood prepared on a saw bench for mouldings should always be cut feather-edged or to a bevel, and the pieces of wood sawn off worked up into small mouldings. It is astonishing even now the number of mill-owners who allow their machines to cut mouldings from a square-sided piece of wood, a large percentage therefore being entirely wasted. These bevelled pieces are easily fed through a moulding machine by substituting for the ordinary parallel feed-rollers narrow rollers, with their periphery serrated and sharply bevelled. Short driving belts are to be avoided in every way, as they simply mean great increase of friction, and consequent deterioration to belt and bearings, with increased difficulty of lubrication. The belting used should be uniform in thickness, and kept as pliable as possible, and sufficiently wide to prevent over-straining. After repeated experiments I can recommend that driving belts should be run with their *outside or smooth surface to the pulley*, which is directly contrary to the plan now usually pursued, the practice being to run the rough or flesh side of the belt on the pulley. I have found that if a belt is evenly made, and smooth on its face, it bears equally over the whole face of the pulley, and not at certain points, as in the rough surface of the flesh side of the leather. With a smooth belt the air is almost entirely excluded, and the driving power considerably increased. To produce a smooth and perfect surface on the wood when planing, much depends on the accuracy with which the knives are sharpened and adjusted on the cutter block. A straight-edge or square should be used to try them at all points. The usual plan of trying them on the wood is not, as a rule, sufficiently accurate. Bottom cutter-blocks are easily adjusted by laying the straight-edge over the opening through which the cutters project, and making each knife touch exactly at every point the edge of the straight-edge. Duplicate sets of tools should be kept on hand in case of accidents. Automatic lubrication should be employed wherever possible, and none but the best lubricants employed for high-speed spindles. All open oil-ways should be protected from dust; the bright parts of machines not in use should be coated with a mixture of white lead and tallow. At least half an hour should be spent at the end of each week in thoroughly cleaning the whole of the working parts of the machines, and the framework should occasionally be painted. This not only preserves the iron, adding to the appearance of the mill, but encourages the workman to take a pride in the condition of his machine. These points are, however, often neglected.

CHAPTER XXXI.

MACHINES FOR ESTATE PURPOSES.

The use of wood-working machinery is gradually extending to that class of work required on country estates—viz. the conversion of timber grown on the estate into boards, gates, posts and rails, fencing, &c., and other articles required in the farm buildings and cottages. Even on estates of moderate size—say, above one thousand acres—steam can doubtless be employed profitably in wood conversion, as, should an engine be used—as in these days of high farming is generally the case—for preparing cattle food, it can be devoted at least one day a week to wood-cutting, and even at this rate will pay a fair interest on the very moderate outlay necessary. Except on large estates, and where skilled men are constantly employed, machines of the plainest and simplest kind are to be preferred, as joinery and mouldings, &c., can usually be purchased cheaper than they can be prepared, at any rate in small quantities. The most convenient machine to use is a plain circular-saw bench, or one fitted with self-acting feed where heavy timber is used. The frame of this bench should be on the 'box,' principle, and especially strong to withstand rough and unskilful usage. The saw spindle should be arranged to rise and fall, so that the driving pulleys may be lowered below the level of the table, so that the whole width of the bench may be utilised for cross-cutting posts and rails, fire wood, &c. A sliding plate, working in a dovetail groove on the top of the bench, running parallel to the saw, and fitted with a cramp for securely holding the wood, should be employed where much accurate cross-cutting is required, such as wood blocks for paving purposes, &c.

The saw fence or guide should be arranged to turn over the end of the bench, out of the way, when not required for straight sawing. The saw spindle should be bored at one end to receive augers for boring or slot-mortising purposes. For estate purposes the addition of a mortising table is of great value. This is best added by arranging the frame of the bench on one side immediately below the saw spindle, with planed strips to receive a sliding table or bracket, which can be raised or lowered vertically by a rack or screw. On this table is fitted a slide, arranged with lateral and transverse movements, and a cramp holds the wood firmly whilst under the action of the mortising tool. The mortises are produced by a revolving routing or slot-mortise tool, the slide carrying the wood at the same time receiving a traverse motion by means of a hand lever. The lengths of the required mortises are governed by adjustable stop-pieces, and the transverse movement of the slide, which is usually worked by a hand wheel and screw, gives the required depths.

Should a further range of work be required, an arrangement for cutting tenons, striking mouldings, or planing can be added. Except where a permanent saw-mill is established, the portable engine is the most useful form to employ for estate purposes.

CHAPTER XXXII.

FRAMINGS OF WOOD-WORKING MACHINES.

When considering the different classes of machines, we have from time to time given hints as to their framing and general construction; but as wood-working, unlike most other machinery, is subject to excessive and constant strains, it may not be out of place to discuss the matter a little more fully. In addition to the ordinary strains of tension, pressure, or shearing stress, the framings of wood-working machines are, subject to an especially severe vibrating strain, arising from the high speeds, arduous duty, change in velocity or direction of motion, which the spindles or working parts are subject to. The ordinary rules for calculating the elastic or breaking strain of the materials employed when designing framing must be considerably modified, allowance being made for excessive vibration, and in some classes of machines for the heavy load, in addition to the ordinary working details the framings have to carry. As we have before mentioned, for some years the framings of wood-working machines were constructed almost entirely of wood, the theory being that wood, being elastic, would, more readily than iron, absorb the excessive vibration. Practical experience has, however, sufficiently disproved this idea, that we will not further discuss it. For all the heavier classes of machines, and some of those with a reciprocating motion, which in their working have a constant jar or vibration, such as steam mortising machines, we prefer the cored or hollow-section framing. This form of framing is doubtless higher in first cost, and somewhat more difficult to manipulate, but this is more than counterbalanced by its increased strength and resistance to stress, economy of material in ratio to strength, and increased compactness and neatness in design.

Much improvement in machine design has doubtless recently been made; but even now we frequently see large quantities of waste material in the framing or supporting brackets, which, if not absolutely injurious, is of no advantage to the working of the machine, whilst other parts, where strength is required and where a 'fillet' or flange in the casting would be of value, is left unprotected; the result is unequal strain, excessive vibration, and inferior work. The same remarks apply with increased force where the metal is 'scamped,' as in the so-called cheap machinery, where general efficiency is sacrificed to low first cost.

Although no absolute rules can be laid down, these defects, with a little practical experience, can easily be obviated, bearing in mind that the various proportions should be judiciously distributed, according to the strains to be put on them; that they should be convenient for the founder, and easily manipulated and renewable, in t[illegible]st instance in the workshop, and afterwards in th[illegible] mill. As regards the allowance to be made in [illegible]ucting framing, in consequence of the constant a[illegible]al vibrating strain it would vary considerably in different classes of machines. In steam mortising machines with a reciprocating motion it would be as high as 25 per cent., whilst in band-sawing machines, where the strain is chiefly torsional and the speed or duty not especially severe, a considerably less percentage would be sufficient. In any case the working stress of framings should always be considerably less than the elastic stress, as the tangential and other strains produced by imperfectly balanced working parts, unequal or excessive duty, lack of speed, undue friction, uneven foundations, or inferior workmanship must not be lost sight of.

Great care should be exercised in the making and finish of the wooden patterns used; inferior woods should never be employed. The best yellow pine is suitable for the larger patterns, and mahogany for the small. Whatever little extra trouble or expense is incurred in making perfect patterns is amply repaid by the casting being much improved in symmetry and requiring less finishing. In machine framings, owing to the difficulty of retaining sharp outlines in cast iron, the profiles should always be bold and simple in design, the edges well rounded, and all hollows, where stability and extra steadiness in working is required, should be supported by suitable fillets or ribs.

Complex forms in machine design are in every way to be avoided. This may appear a somewhat trite, but it is certainly not an unnecessary, remark in these days of fierce competition and straining after originality, and young engineers may bear in mind with advantage the saying of James Watt that 'the greatest of all prerogatives is simplicity, but more especially when applied to machinery.'

If iron patterns are used, which is advantageous when a large number of castings are required, allowance must be made in the wooden pattern in the first instance for the contraction in casting in the subsequent cooling. It is somewhat difficult to determine accurately the amount of this contraction, which varies according to the size and thickness of the casting, the nature of the iron, and the rapidity of cooling; but for framing castings of medium size—say, up to two tons in weight—composed of iron of fair quality and cooled slowly, a calculation for contraction of about one-eighth of an inch per foot in either direction would, we think, be safe. The thickness of the metal in machine framings should always be as uniform or gradual as possible, so that the contraction of the molten iron in cooling may be tolerably equal. The sudden changes in a casting from thin to thick metal should be avoided, as they produce a degree of initial stress which lessens considerably its strength, strains and twists it out of shape, and at times even fractures it. Each part of a machine frame or details should, as far as possible, be calculated to bear easily the highest amount of straining action of whatever kind that is usually put on it whilst performing the severest duty of which the machine is capable. The exact calculation of these various and somewhat complex strains is, however, difficult, and must, after a certain point, be left almost entirely to practical experience. If motion or load is suddenly applied, the stress on both framing and wearing parts is much increased. This of course is especially noticeable in high-speeded machines; care therefore should be taken that the application of the belt or other power for producing motion should be very gradual. This is a point we are afraid, that is often overlooked, but one that adds considerably to the longevity of a machine. We have found the application of a quick-threaded screw for starting or stopping belts a simple and effectual method of gradually applying this power.

For machines where the speed is moderate and the duty light, framings with ribbed sections have some advantages, notably that of cheapness and easy manipulation; but on the whole tubular or cored framing, with its various modifications, is much to be preferred.

Care must be taken that the mixture of iron employed is of good quality, and produces sound castings free from air bubbles or honeycombs. When broken, the iron should appear close in the grain and of a light bluish-grey colour. Unsound castings, or those showing a mottled appearance, should never be employed where they may be subject to any considerable strain. The surface of the castings should be made as clean as possible, any little extra expenditure in this direction amply repaying itself in their appearance and strength. But how often do we see a pound a ton saved in the first cost more than spent in making the castings presentable by chipping them over their surface, reducing at the same time considerably their resistance to stress by removing the outer skin of the iron. By casting the iron under pressure much sounder castings are produced, but the difficulties and cost of the process preclude its use, except for plain and well-defined articles and when expense is not of the greatest importance. Air bubbles or honeycombs may be detected after a little experience, by ringing a hammer over the surface of the casting.

Especial care must be taken in designing the framing of machines with a reciprocating motion, such as timber frames, mortising machines, &c., with a view of overcoming the excessive vibration. In America the main uprights of timber frames of large size are often constructed of wood, and attached to or combined with the timber supports of the building itself. By these means the jar and vibration is in a great degree absorbed, and saw frames constructed on this plan are found to work with a considerable amount of success. They are, however, open to objections for English use, and are on the whole somewhat cumbersome and inconvenient. Occasionally the heavier saw frames are arranged with an air cylinder, or to drive directly from a steam cylinder attached to the top of the frame. These plans have some advantages, and the vibration in working is considerably lessened, the air or steam acting as a cushion at each stroke of the swing frame. Latterly saw frames arranged with their crank shafts to work on a level with the floor lines have been introduced. This is accomplished by making the vertical standards of the frame of unusual solidity, and attaching them and the working parts to a massive bedplate, or, in the case of light bed-frames, casting standards and bed plate in one piece. For light frames this arrangement is sometimes advantageous, but for heavy frames it is not to be recommended, and should never be pursued unless, from water or other causes, deep foundations cannot be obtained. Under all ordinary circumstances we are much in favour of a frame arranged with a pit crank-shaft, and whatever extra cost may be incurred in the way of foundations is repaid by decrease of vibration, which is absorbed by the masonry foundations instead of the mill floor. The work turned out is consequently cleaner.

In mortising machines with a reciprocating motion the base of the main column should be of massive construction, and the bed plate extended, as the duty in heavy machines is very severe.

With machines working on the rotary principle the stress on the framing is less severe; but very much depends in balancing all cutter blocks to the greatest nicety, as, should they be only slightly out of truth, owing to the immense centrifugal force at work, the adverse stress exercised on all parts of the machine is very great. All cutter-block spindles too should be of sufficient section to obviate all chance of springing even under the severest duty, and the spindle bearings should never be allowed much 'play,' or the vibration, which is often attributed to weak framings, is much increased.

As regards the design of the spindles and details used in the construction of wood-working machinery, if wrought iron is used, only that of the best quality should be employed, combining strength and toughness. This, when the bar is fractured, is shown by the fibres of the iron being close and uniform in the grain, free from whiteness or crystallisation, and of a bright blue-grey colour. The dimensions of spindles should be as uniform as possible, avoiding abrupt angles and sudden changes of diameter. Where spindles are subject to much strain the alteration of diameter should be graduated by a curve, or what is known as rounded off, as any shock or vibration is thus more evenly distributed. For all the smaller diameters of spindles we prefer to use Bessemer or other mild steel, and the cost is very little in excess of the best wrought iron. It is of course rather more difficult to work, but this is repaid by a finer surface being obtainable, as wrought iron is often found seamy, or, by the fibres of the iron not running parallel to the length of the bar, the abrasion of the surface, and consequent friction on the bearings, is much increased. In forging spindles, or any parts on which there is great strain, as few 'heats' as possible should be taken by the smith, as by constant reheatings the strength of the bar is considerably reduced. Great care also should be taken that collars or journals, or any forgings necessitating a number of heats, are not burnt, as we have more than once, especially in steel spindles, seen them from this cause break short off at the angle on receiving only a very moderate shock or blow.

CHAPTER XXXIII.

BEARINGS FOR WOOD-WORKING MACHINERY.

IN consequence of the high rate of speed at which it is necessary to operate wood-working machinery, the proper proportion, construction, and lubrication of the bearings—whereby the friction necessarily engendered can be reduced to its lowest limits—is a matter of vital importance. Much time has been spent by scientific men in investigating the theory of friction, and many learned treatises written thereon. One of the most valuable of the earlier ones with which we are acquainted was written by George Rennie, F.R.S., and published in the 'Philosophical Transactions' for 1829. In this paper he gives briefly some of the deductions made by the earliest writers on this subject, including Amontons, who wrote in the year 1669, giving as his opinion that friction was not augmented by an increase of surface, but only by an increase of pressure, and that the amount was the same both with woods and metals when unguents were interposed. He likewise concluded that friction increased or diminished with the velocity, and varied in the ratio of the weight and pressure of the rubbing parts and the time and velocity of their motions. Most of the scientific men following Amontons agreed with his hypotheses, including De la Hire. Experiments as to the theory of friction were also made by Vince and Coulomb in 1784 and 1799. Following these, Euler concluded that it depended on the greater or less approximation of the asperities of the surface brought into contact by pressure, the resistance to which he agreed was one-third of the pressure; of the effect of velocities he was uncertain. Muschenbroek and others maintained that friction increased with the surface. Bossut divided it into two kinds, the first being generated by the gliding, and the second by the rolling of the surface of one body over another; he also concluded that it was effected by time, but that it followed neither the ratio of the pressure nor of the mass. A great number of other scientific men, including Lambert, Parent, Brisson, Camus, Schober, Meister, Leibnitz, Varignon, Bernouilli, Ferguson, Gregory, Leslie, Bulfinger, Young, &c., early in this century wrote on the theories of friction.

In the year 1784 De Vince made a number of experiments to determine the law of retardation, together with the quantity and the effect of surface on friction. He was of opinion that the friction of hard bodies in motion was an uniformly retarding force, but not so with soft bodies, such as cloth, which produced an increase of retardation with an increased velocity, and also that the quantity of friction amounted to about one-fourth the pressure, and that it increased in a less ratio than the weight of the body; that when the surfaces varied from 1·61 : 1 to 10·06 : 1 the smallest surface gave the least friction, and that friction was greatly influenced by cohesion.

A very elaborate series of experiments on the laws of friction were undertaken by Coulomb at the instance of the French Academy of Sciences in the year 1799. He commences by examining the friction of plane surfaces gliding over each other, and divides it into two kinds, the first resulting from time and the second from velocity. The first he considers to depend on five different causes—(1) the nature of the bodies in contact; (2) the extent of surface; (3) the pressure on the surface; (4) the time the surfaces have been in contact; and (5) the state of the atmosphere. He was also of the opinion that the friction of wood on wood, and metal on metal without unguents, was in proportion to the pressure, which attained its maximum in a few minutes after repose, and that with heterogeneous surfaces, such as those of woods and metals gliding over each other, the intensity did not attain its limit sometimes for days. He also concluded that velocities had very little influence in augmenting friction except under peculiar circumstances.

In 1801 Mr. Southern, of Soho, made experiments on the surfaces of the spindles of grindstones running at a high speed, when he decided that, with rubbing surfaces moving at the rate of 4 feet per second over a length of surface of 1,000 feet, the resistance arising from the friction of 3,700 lbs. of load amounted to one-fortieth of the weight.

Mr. George Rennie's experiments on the laws of friction were on a very extended and complete scale, but our space prevents our giving as lengthened a description as we should wish. His deductions, however, were as follows:—(1) that the friction of metals varies with their hardness; (2) that the hard metals have less friction than the soft ones; (3) that without unguents, and within the limits of 32 lbs. 8 ounces per square inch, the friction of hard metals against hard metals may be estimated at about one-sixth of the pressure; (4) that within the limits of their abrasion the friction of metals is nearly alike.

For determining the friction of axles Mr. Rennie arranged an apparatus consisting of a roller with accurately turned, movable ends; these were made of three different metals—viz. cast iron, gun metal, and yellow brass. The axle ran in bearings, truly bored in cast iron, leaving the axle full play. A cord was attached to the roller, passed over a pulley carrying a scale in which the moving weights were placed. The axle projected beyond the bearings, and on this slings were hung, and carried the scale which held the weights with which the axle was loaded. The rope pulley was made very sensitive, and the descent of the body was only $4\frac{1}{2}$ inches. From experiments made with this apparatus, it appeared when no unguents were employed, and when the gun metal was loaded with variable weights from 1 to 10 cwt., the friction varied within the limits of $\frac{1}{76}$ and $\frac{1}{47}$ of the pressure; that the diminution of friction by unguents depends upon the weight and the unguents conjointly.

Rennie also made a series of experiments on the amount of friction as depending on velocity. From these experiments he concluded that friction did not increase with an increase of velocity. Since Rennie's a number of excellent treatises on the laws and coefficients of friction have been published, notably by Morin, Welkner, Bokelberg, and others, and most of Rennie's deductions have been upheld; and although his experiments were made some fifty years since, they are of much practical value to engineers of the present day. Joule and Thompson divide friction briefly into two kinds—*sliding* and *rolling*—and maintain that the quantity of frictional heat evolved is exactly sufficient to reproduce the effort caused in overcoming the friction. As most of the more modern treatises on friction are doubtless known to many readers, I shall pass them with a casual reference only.

Bearings for wood-working machinery are usually made of cylindrical form, but sometimes conical or spherical, and to ensure coolness in working and durability, owing to the excessive friction engendered, they should be of special proportions. No hard and fast rule for calculating the length and diameters of bearings of wood-working machinery can well be laid down, owing to the difficulty of calculating exactly the amount of friction. Bokelberg gives the coefficients of friction as 0·0028 for small loads and low velocities, and 0·013 for heavy loads and high velocities. Of course these coefficients must differ according to the condition of the bearings and the lubrication of the metal employed. Morin gives 0·05 to 0·07 as the coefficient for well-lubricated bearings, whilst, according to experiments made by Kirchweger on railway axles, the coefficient of friction of wrought iron on gun metal is found to be 0·014, whilst wrought iron on white metal is set down as 0·009 to 0·01. Whichever calculations are most correct, owing to the varying and special conditions under which the bearings of high-speeded machinery are employed, practical experience must of necessity be the chief guide as to their correct proportions, of course bearing in mind also what pressure and straining forces they are likely to be subject to. In America as a rule engineers make their spindles much smaller and their bearings longer than is the practice in this country. We are not aware, however, on what data their calculations as to proportions are based. To ensure durability and small friction to bearings which support spindles running at high speeds, a considerable amount of bearing surface is necessary. To secure this it is better to extend the bearing in length than increase its diameter. In calculating the correct proportions of bearings, the kind of metal employed, the action to which it is subject, and the mode of lubrication are points, in addition to the pressure and straining forces, before alluded to, that must not be lost sight of. As regards the length of bearings for high-speeded machinery, from three to four diameters may be taken as a safe criterion for spindles that are constantly running at speeds, say, up to 5,000 revolutions per minute; above that speed the length of the bearing can be increased, say, one or one and a half diameter with advantage; for spindles that only work occasionally and at a slower speed they may be made shorter, and the spindles of less diameter for a given duty, the friction in consequence being reduced. Various mechanical arrangements for reducing friction have been tried, but, as a rule, with little success. In the year 1845 Mr. John Blyth, of London, patented a plan for preventing the heating of bearings by means of cold water. The bearings were constructed with a hollow cavity in the shell, through which a stream of cold water was passed, and in the case of bearings which moved round an external axis, as in connecting rods, flexible pipes were used to conduct the water. A Mr. Coles, of London, soon after this invented a system of anti-friction bearings, in which, in place of the rubbing action of the spindle, he substituted the rolling action of detached pulleys. A Mr. Mallett, of Dublin, also patented a scheme for reducing friction. In the place of pulleys, however, he substituted a set of rollers of small diameter, which were confined in a box directly surrounding the bearings. None of these plans, however, came into use.

The idea of reducing friction by rolling bearings is not by any means new. On several American railways some of the most recent rolling stock has been fitted with steel axles revolving on some sixty hardened steel rolls, so arranged that no two rolls are in line with each other. These are enclosed in a box lined with hardened steel, and receive the whole of the friction of the axle; they are worked without lubricants, and are reported to reduce the friction in a very marked degree even when heavily loaded. Elliptical or egg-shaped rollers have also been tried. These are either mounted on spindles or, where single sets of rollers only are used, the ends of the rollers are turned to act as such; where more than one roller in the same line is used a washer is placed between each one. The whole set of rollers are at liberty to revolve round the shaft and plummer block, which is lined with hard metal.

In this country the materials used for the bearings of high-speeded machinery are almost and entirely confined to gun metal, occasionally white metal alloys, and an alloy of later introduction known as phosphor bronze. If gun metal is used it should contain sufficient admixture of tin to produce a certain amount of hardness; about 18 parts of tin to 82 of copper is a suitable proportion. The bearings should be cast in chills, as rapid cooling is found to give a kind of 'skin' to the surface, improve the metal in toughness, and its wearing power is increased. The alloy 'phosphor bronze' is found to possess in a marked degree strength, toughness, and durability. It is a combination of copper, tin, and phosphorus, which can be so regulated that castings as hard as steel or as tough as wrought iron can be produced, as circumstances may require. The fluidity of this alloy is very great, producing castings of perfect soundness and very fine in the grain. The writer some few years back introduced it into the bearings of grinding and disintegrating mills with spindles making some 3,500 revolutions per minute, and, although the duty was severe, after six months' use the wear was scarcely perceptible. The lubricant used was lard oil. From experiments it has been proved to have a tenacity of 22 tons per square inch in the softer alloys to 33 tons in the hardest; the elastic limit of the former is about 5 tons, and the latter 25 tons. The soft alloy stretches 30 per cent. before fracture, and the hardest not more than 4 per cent. Samples of unannealed wire of 16 B.W.G. broke at from 102 tons per square inch to 151 tons, and when annealed at 48 to 74 tons per square inch. It is also stated that a bar of phosphor bronze has resisted without rupture over 2½ million twists at a strain of 12 tons.

In the International Exhibition, 1878, at Paris, a number of bearings, slide valves, piston rings, pinions, &c., made of phosphor bronze were exhibited. These had been tried under varying conditions, and in some cases in competition with gun metal, and the results were vastly in favour of phosphor bronze. We especially noticed a set of gun-metal and phosphor-bronze bearings that were used side by side in crushing rolls, working at 120 revolutions per minute, each roll having a pressure of 2½ tons. These bearings were at work a year and nine months night and day, and when removed the wear on the phosphor bronze was very small indeed, whilst the gun metal was entirely worn through. Notwithstanding that phosphor bronze is more costly and somewhat more difficult to manipulate, it must be considered a most valuable alloy, not only for bearings but for bolts, pins, &c., where great tensile strength is required.

An alloy for bearings, composed of tin and phosphorus, has recently been introduced on the Continent. It is claimed for it that it is easily fusible, melts at 330° C. (626° F.), does not heat, and therefore requires little lubrication. Its shrinkage is little and it is unaffected by acids. If it is found to fulfil all these conditions it should be of considerable value for some classes of moulded bearings.

In direct contrast to English practice, American engineers almost invariably make or line the bearings of their wood working machinery with a soft alloy, such as Babbitt metal or Parson's white brass. These alloys are melted and moulded or poured round the spindles which have to run in them. Considerable care has to be exercised in this operation, and the spindle set to a dead level. The metal should not be over hot, and both sides of the bearing should be poured at the same time. The bearing should then be scraped and the spindle 'bedded' in the usual manner. A large number of white metal alloys have been introduced during the last thirty years by Grafton, Vaucher, Parsons, Jones, Lechesne, and others. Lechesne patented an alloy in which he used cadmium in combination with other metals. The formulæ were as follows:—Copper, 650 parts; nickel, 275 parts; cadmium, zinc, and tin, 25 parts. Cadmium is malleable and fuses at a low heat, but volatilises rapidly, and considerable difficulty is experienced in combining it with other metals; but, from its nature, we should imagine it would produce a fine surface on the bearing, and consequently reduce friction. The alloy most popular in America is known as Babbitt metal, which is a misnomer, as the invention of Mr. Isaac Babbitt, which was patented in America some forty years ago, consisted in constructing the bearing with a lip around the edge of the soft metal, to prevent it running out, and not in any mixture of metals. In addition to Babbitt's, different forms of bearings have been introduced in America by Rice, Goodman, and others. As Goodman's invention, introduced in 1855, is somewhat novel and departs from the beaten track, it deserves more than a passing notice. The novelty in this bearing consisted in the substitution of a bearing surface of some vegetable substance, such as hemp, saturated with a mixture of tallow, sulphur, and black-lead. The bearings were made of cast iron, and a series of ribs extended longitudinally the whole length of the bearing. The space between these ribs was fitted tightly with either hemp, flax, wool, cotton, or shavings of leather. The durability of the material employed seems to have been established; but, either from its resistance to motion and the extra power therefore required to drive, or from some other cause, it seems never to have come much into use. As regards white metal alloys for bearings of high-speeded machinery, after considerable experience we cannot speak in their favour; there may be less friction in their use, and they may be somewhat cheaper in their first cost, but, as they require constant renewals, anything gained in this way is soon lost. For spindles running at moderate speeds and without a heavy load or strain they doubtless possess some advantages, either when used as linings or as solid bearings; but for high speeds and energetic friction they cannot be recommended.

All the chief bearings of high-speeded machines should be made adjustable for wear. This is especially important where there is a great 'pull' on the spindle. This compensation is easily secured by dividing the bearing vertically and at unequal distances, and fitting set screws through the sides of the journal. Arrangements should also be made for taking up the end play of the spindle. From the high speed and the dust and grit floating about in saw mills, the bearings of wood-working machinery, unless well fitted and well looked after, are especially liable to 'fire' or 'seize.' If this should be the case, they should be at once taken out and the faces of the bearing let closer together, the abrasions being removed by a 'scraper' and the bearings accurately rebedded on the spindle. Should this not be done, considerable trouble will be found in keeping it running even with excessive lubrication. Very great care should always be exercised in fitting bearings, the spindles being bedded with red lead and the bearings scraped till the spindle runs easily at a dead level; they should not fit the spindle too tight nor yet too loose. In the lightest class of high-speeded spindles centre bearings with end adjustments have some advantages, but for the general range of machines we think the ordinary parallel cylindrical bearings, taking everything into consideration, are to be preferred to any other form. When cheapness of production is essential we can strongly recommend the use of cast iron for bearings, as a steel spindle revolving on sound cast iron of not too hard a texture is found to produce a fine surface.

For bearings such as those used in machines with a reciprocating motion, that are difficult, from dust or other causes, to keep lubricated, some kinds of wood, although little used in this country, have many advantages. Lignum vitæ, box, and pear-tree woods are suitable for this purpose; but all resinous woods are unsuitable. All bearings should be guarded from dust as much as possible, and very efficient lubrication secured. This in connecting-rod and some other bearings subject to excessive friction is often a matter of some little difficulty. We have found a brass needle lubricator, constructed on what is known as Lieuvain's patent, tolerably effective for ordinary purposes; but where the friction is great an additional tallow cup should be provided, the tallow in which would melt in case of the bearing heating. For metal rubbing on wood, water is found to be an excellent lubricant. Sulphur, blacklead, or plumbago reduced to a fine powder and mixed with the oil or tallow applied to the bearing is found to retain the lubricative qualities of the oil, and reduces the friction considerably. We have recently heard soap-stone very highly spoken of as a lubricant for high-speeded spindles. It is first reduced to a very fine powder, and washed to remove all gritty particles; it is then stirred in diluted muriatic acid, to dissolve any traces of iron it may contain. The powder is then re-washed in water to remove the acid, dried, and mixed with oils or fats in the proportion of about 25 per cent.

for light machinery to about 40 per cent. for heavy machinery running at a somewhat slower speed. It is said to retain well the oleaginous properties of the lubricant, and to produce a very fine surface on the bearing. We have found pure sperm and olive oils very fine lubricants, but their cost in a degree precludes their use, except for light spindles. An antifriction grease composed of hog's lard, guttapercha, and powdered blacklead is much used in the United States. All fat oils should be stored in a moderate temperature. If exposed to much heat they are found to decompose and lose their oleaginous properties. We have also used pure castor oil with very considerable success, as it is free from acid, does not clog, and, owing to its clinging properties, does not run out of the bearing. Self-oiling bearings of various kinds have been patented and introduced, with more or less success. One of American origin, patented in 1865 and made by J. A. Fay and Co. and other firms, is especially adapted for circular-saw spindles. The two pedestals are cast at either end of a bracket, which is furnished with oil chambers, connected together by a recess extending diagonally. The oil is conducted from the chamber to the bearings by means of cotton wick or felt, which is fitted in the before-mentioned recess, and, after passing through the bearing, works its way back to the chambers. The oil is thus kept in constant circulation.

The spindles used in high-speeded machinery should be made of the soundest material possible, as, no matter how well constructed and lubricated bearings may be, if the spindles are seamy the friction is much increased, and considerable difficulty is found in keeping them running. All cutter blocks and pulleys should be accurately balanced. They should never be worked at short centres; and all driving belts should be of ample width; the transverse strain, which is so destructive to bearings, is thus minimised, and the cost of belting and lubrication reduced. Steel is to be recommended for spindles in preference to iron, on account of its homogeneity and rigidness. By its use the diameter of the spindles can also be reduced considerably—say, about one-fourth.

In machines whose cutter blocks have only one bearing immediately supporting it, such as overhung-cutter moulding machines, vertical-spindle shaping machines, &c., the superior rigidity of steel is especially valuable, as, should the spindles spring from the excessive pressure which they are sometimes subject to, the bearings are rapidly destroyed and the work turned out is of an inferior description.

'Footstep' bearings, or those on which the lower ends of a vertical spindle rest, are usually solid, a cup- or obtuse V-shaped recess being turned in one end of the bush in which the spindle revolves; sometimes, however, conical bearings are substituted. In either case these bearings should have both lateral and vertical adjustments; and, as the dust made in working necessarily absorbs much of the lubricating matter, a recess for oil having direct communication with the bearing surface should be formed in the pedestal in which the bearing is fitted. Should a bearing become heated or 'seize,' pour cold water on it till thoroughly cool This heating often occurs with new bearings, and may arise from several causes—viz. want of lubrication, the bearing or spindle being out of truth or badly fitted, from a 'seamy' spindle or the bearing being screwed down too tight. Should the bearing be much abraded by the friction, it will be necessary to remove the spindle and 'scrape' the bearing before restarting. The level of the spindle should be tried, and the bearings well lubricated; the cap screwed down lightly, and the spindle worked for a short time without performing any duty.

If conical bearings are used care must be taken that the spindles are allowed no end play. This can be secured by fitting a steel pin, screwed at its own end and passed through the end of the bearing till it touches the end of the revolving spindle. The steel pin can be set up by a nut, and the end nearest the spindle should be of somewhat smaller diameter, and a flat filed on its side, which will form an efficient oilway.

In practice it is often found more difficult to keep bearings well lubricated that are subject to constant and great pressure than those which carry spindles revolving at high speeds, as, from the weight of the load, after running a short time their unguents are expelled from the bearings unless especial provision is made. For this class of bearings unguents with a metallic base, such as plumbago, are found the most efficient. A dry metallic composition has recently been introduced for lubricating purposes, it is made in the form of small cylindrical plugs and inserted in holes made in the solid bearings or surfaces requiring lubricating. It is reported to bear a temperature of 450° Fahr. It is known as 'metaline,' but we cannot from our own experience speak as to its value.

CHAPTER XXXIV.

MACHINE FOUNDATIONS.

The proper fixing on adequate foundations has much to do with the satisfactory performance of wood-working machinery. In the case of machines working on the rotary principle little difficulty is experienced as regards foundations, the stress being as a rule easily absorbed by well-apportioned framing—that is, on the assumption that the working parts are all truly balanced and fitted. With machines with a reciprocating action, however, it is different; considerable difficulty is sometimes found in arranging them to operate with a minimum of vibration.

Conditions sometimes arise in consequence of proximity to tidal rivers, or on undrained land, where, before a machine requiring a deep foundation can be fixed, especial means must be taken to get, in the first instance, a solid basis. Where the water is very troublesome and difficult to get rid of, and where the weight to be supported and vibration to be absorbed are considerable, as in the heaviest class of log-sawing frames, we have found a series of English elm piles to make the most durable and satisfactory foundation. The distance apart, and the depth they should be driven, must depend on the action of the machine, the weight of the load, and the nature of the soil. The tops of the piles should be sawn off level, and sleepers or planks fixed transversely on the top of them. This will make a safe and lasting foundation. The piles and sleepers should be creosoted. It is also advisable that the machine should be fixed on an extended bed-plate of extra massive section. When the ground is moist only, and much concrete is unnecessary, a good plan is to ram the substratum firm, and cover with a layer of broken stone or slag to about 6 inches in depth. Into this layer pour melted asphalt. This, when cold, binds together in one solid mass, prevents damp, and gives a strong foundation for the subsequent masonry.

To reduce the depth and lessen the cost of excavations, saw frames should be connected to the crank shaft by two rods, one on either side of the frame. The vibration is also reduced considerably by counterbalancing the reciprocating parts, and by arranging the crank shaft as near the base of the machine as possible; with saw frames a fly wheel or wheels is found to add considerably to their steadiness in working. If the saw frame is fixed on masonry, we have found the vibration considerably lessened by the introduction of a sheet of lead or a thin piece of hard wood between the base of the machine and crank-shaft plummer-blocks and the masonry. As regards the masonry employed, stone is of course stronger and more solid, and offers a better resistance to vibration, than any other, but its greatly increased cost is somewhat of a bar to its general adoption for all classes of machinery. The strength of a stone foundation depends in a great measure on the quality of the stone employed, and also that the size and shape of the blocks used are in proportion to the strength of the stone. The mortar, too, used for this purpose should be of the very first quality; and the stones accurately dressed. If the dressing is badly done, and the pressure is unequal and severe, they are liable to fracture. Some classes of stone can safely be employed for machine foundation in blocks of almost any size, but in others the sizes of the blocks should be proportional. A safe rule is to make the length of the block, say, about three times the thickness, and the width one and a half times; blocks of long dimensions in proportion to their thickness should never be used, as with heavy machines with a reciprocating motion, with a positive stroke or dead blow, the risk of breakage is considerable. Care must be taken that the masonry is accurately levelled, and set as near perpendicular to the direction of the stress or pressure as possible. The top blocks of stone should be cramped together, and the joints filled in with molten lead. The horizontal mortar joints should be from $\frac{1}{4}$ to $\frac{3}{8}$ inch in thickness, and the vertical joints about $\frac{3}{16}$ inch. These various precautions may appear to some to be slightly unnecessary, but, as excessive vibration and stress is in a great measure overcome by the weight and solidity of the foundation, the framing of the machine being as far as possible combined with and, so to speak, made integral with the foundation, this can hardly be so. The quality of the work turned out and the longevity of the machine depend also more on the stability of the foundations than is generally imagined. The foundation bolts should be of strong section, and the plates of ample area. The bolts should pass entirely through the masonry, and we have found there is less liability to fracture or work loose by any sudden strain by intervening a piece of hard wood between the plates and the masonry. Wood-working machines with a reciprocating motion should never be placed on a wooden floor, except those of the very lightest class, and even these should be accurately balanced. In constructing machines with a reciprocating motion it may be taken as a safe rule that the machine framing and foundations should be made as solid and stable as possible, whilst the reciprocating parts should combine strength with lightness. In machines with a rotary motion and the straining forces acting horizontally to the axis of motion, brick-work or timber foundations are usually sufficient, but for the heaviest class of machines, such as rack-saw benches or planing machines, if the earth foundations are at all unsound, concrete or rubble masonry are to be preferred; but for all kinds of foundation where great strength and solidity are required ashlar masonry is undoubtedly the best, and we are of opinion that any reasonable extra cost incurred in the shape of perfect foundations for high-speeded machines is more than repaid by increased steadiness in working and consequent improved quality of output. As a rule of course inferior production in machines with a rotary motion is directly traceable to loose bearings, weak spindles, or insecure bearings, improperly sharpened cutters or unbalanced cutter blocks; but it cannot be denied that, in the first instance, weak or insecure foundations contribute largely, through imperfectly absorbing the stress or vibration, to bring about some of these results, especially in machines with their framings put together in sections. If brick-work foundations are used, care should be taken that the bricks employed are hard and well burnt, and Portland or Roman cement only should be used. This is especially necessary in damp situations, as some classes of bricks are found to absorb a considerable amount of moisture, and this, combined with unequal settling, destroys the rigidity and stability of the masonry.

CHAPTER XXXV.

SHAFTING AND GEARING.

In order to ensure the economic transmission of power by means of line shafting from the motor to the various machines, the whole of the shafting should be accurately turned and fitted at a dead level, in bearings having both vertical and lateral adjustment, and provided with efficient means of lubrication. All pulleys should be turned, rounded somewhat on face, and perfectly balanced. The shafting should be speeded to make not less than 250 revolutions per minute, and all pulleys therefore should be accurately proportioned and all superfluous weight of metal avoided.

We are afraid many of these points do not receive in this country the attention they deserve, which is in striking contrast to American practice, which has worked out and brought them to a considerable degree of perfection.

Shafts for transmitting power to different parts of a building were at one time constructed of wood or cast iron; these, however, have given way to wrought iron, or in some cases to Bessemer steel, which in shafts of small diameter has the advantage of additional stiffness. Line shafting is subjected to considerable torsional and bending strains, but more especially in saw mills, where the speed, number of pulleys, and belt tension is excessive. This should be borne in mind when calculating the diameter of the shafting and the centres of the bearings to be employed.

In arranging shafting for a mill, the first length, which receives the power from the prime mover, should be of greater diameter than the remainder, and the bearings placed closer together—say, five or six feet apart, whilst eight or nine feet apart on the ordinary shafting will be sufficient. To prevent end play, a collar should be fitted against the bearings at either end of the shaft. The driving pulleys on which there is the greatest strain should be placed as near the bearings as possible, to avoid any chance of the shaft springing, should any undue strain be put upon it.

In calculating the diameter of a shaft it will be found much better to err on the side of strength, as, should a shaft spring from insufficiency of size, the money lost in stoppages, lining up, &c., would in a very short period pay for the difference in first cost.

In coupling lengths of shafting the plan of using a solid sleeve or box of metal keyed to the shaft is still generally adhered to in this country, for what reason we are at a loss to see, as it is both clumsy and inconvenient.

A very light and convenient form of coupling, much used in the United States, is known as the double-cone vice coupling, originally introduced and patented, we believe, by Messrs. William Sellers and Co., of Philadelphia. It consists of a cylindrical barrel, which couples the shafts. The inside of this barrel is turned to a double conical form; between the barrel and the shaft are fitted two sleeves, the outsides of which are conical and fit the box, and the insides are bored to fit the shaft. These sleeves are cut completely through on one side, and are made to close concentrically upon the shaft by means of three square bolts fitted in slots cut into the sleeves and barrel, and running parallel to the shaft. These couplings have the additional advantage of being easily uncoupled in the centre of a shaft for placing or removing pulleys, without the great trouble of drifting keys, as in the ordinary box coupling.

All bearings should have a perfectly rigid seat and be well lubricated. Various plans of self-lubrication have been tried, with more or less success. Where belts have to be run at high speeds, especially when over small pulleys and at short centres, a great loss of power, increased friction, and consequent deterioration of belts is occasioned by the belts slipping on the face of the pulley. To obviate this powdered resin and various other substances are used to increase the grip of the belt, but these have the disadvantage of having to be constantly applied and at the same time destroy the belt. We have seen recently in use a peculiarly prepared paper, which is cut into strips the width of the face of the pulley and several layers cemented on together. On the pulley of a dynamo-electric machine on which we saw it tried, the belt ran truer than on a plain pulley, and the contact of the belt was more uniform; a steadier light was consequently produced. We think altogether the plan of covering pulley-faces with paper, to prevent slipping of belts, is so far successful that it is deserving of further and more extended experiments under varying conditions to determine fully its merits, and the exact gain, if possible, in power, motion, and in loss of friction, accruing from its use.

A flat endless band of indiarubber and canvas, the face nearest the pulley being unvulcanised, can also be used with advantage for increasing the gripping power of the belt. It should be made of less radius than the pulley—say, about one inch to the foot—stretched on to it as tight as possible, and cemented.

With a view of reducing friction and economising oil, Mr. A. Barclay, of Kilmarnock, in 1854 invented and patented an improved journal and bearing for horizontal shafts, in which the oil would be repeatedly re-used. This was carried out by forming the bearings to extend considerably beyond the collars of the journal; the extended ends of the bearings were hollowed out internally to form oil cups; the oil, supplied from the top in the usual way, passed over the frictional surfaces, and was caught in the annular cups. The oil was re-used by means of the bearing collars, which, as they revolved, caught it up and carried it to the top bearing, part of the inner faces of which were inclined upwards towards the centre, leaving a way for the oil, which was thus redistributed over the rubbing surfaces. Many modifications of this plan of lubrication have been tried. One journal, patented by Möhler, has a bottom bearing only, which is divided into two parts by a collar on the spindle; the lower part of the journal is made hollow, and forms a reservoir for the oil, into which the collar dips, and as it revolves it re-distributes the oil to the bearing on either side. There are objections, however, to this plan of lubrication, as, after the oil has been used some time, it is found to absorb an excess of oxygen, which renders it comparatively useless.

A self-lubricating bearing of some novelty was patented as recently as 1878 by Messrs. Chapman and Sutton, of London. In their invention the bearing block is recessed to form an oil chamber. A narrow roller is mounted in this recess, having its lower part immersed in the oil and its upper part in contact with the shaft through an opening cut in the bearing. When the shaft revolves the smaller roller revolves also, thus constantly bringing the oil from the chamber to the shaft as long as the motion continues; when the shaft stops the lubrication ceases. The oil, after being used on the bearing, is received in a channel and conducted back to the oil chamber for re-using.

Main driving pulleys which transmit a large amount of power should be of extra strong section, and in some cases should be constructed with double arms. All loose pulleys should be bushed with gun metal and kept well lubricated. The boss of the loose pulley should be at least twice the length of the fast. As regards lubrication, we have seen many plans, but nothing better than the old-fashioned one of drilling a hole through the rim of pulley and boss, and fitting into it a piece of gas piping, which is tapped at its top end, and a flat-headed screw let in flush with the periphery. Constant care must be given to loose pulleys, or considerable trouble will be found in keeping them in order. Pulleys made of wrought iron have come somewhat extensively into use of late years; they possess the advantage of lightness and strength and are easily fixed. To obviate the constant tension of the belt a Mr. Streit patented in 1877 an arrangement of making the fast and loose pulleys of varying diameters, the loose pulley being made of less diameter than the fast. The belt is relieved from all strain whilst running on it, and the friction on the shaft is reduced to a minimum, being that only engendered by the weight of the belt. The belt also has time to recover its elasticity, and therefore wears longer, as it is found in practice that when a belt once reaches the limits of its elasticity it very rapidly deteriorates. The plan of using fast and loose pulleys of varying diameters cannot, however, be considered altogether novel. In stopping and starting high-speeded machines care should be taken that the belt is passed from the loose to the tight pulley very gradually by means of a screw or some similar method, as the shock occasioned by starting a heavy machine suddenly is very considerable, and is decidedly detrimental to the working parts of the machine.

In place of the old-fashioned form of clutch coupling, which is open to many objections, we can confidently recommend the employment of a friction band; it can be applied to pulleys round the boss of the wheel, the pulley in the first place being fitted on a flanged bush or sleeve keyed to the shaft. The friction band is split, and fitted with a bolt having a cam-shaped head, which engages with another cam on the friction band; a curved lever is attached to this bolt, and is engaged by a cone on the shaft; the cone is grooved and worked by a shifting lever, and when moved towards the pulley the friction band is contracted round the boss of the wheel and carried round with the shaft, or *vice versa*.

As regards toothed gearing for transmitting motion, we need hardly say it should be constructed on true mathematical principles, and especial care should be taken that the wheels are moulded very accurately and the right amount of taper given to the teeth. From bad moulding, warping of pattern, or carelessness in machine moulding, a large number of the toothed wheels turned out are very inferior. The teeth are often allowed to bear on each other on one side, and being usually made of cast iron, constant breakages are the result of any sudden strain. In practice we have found machine-moulded wheels to be the most accurate. For intermediate pinions or wheels where great strength is required the teeth are often cut from the solid by a machine, but the great extra cost precludes their use except for special purposes. Where the friction is very great we have found wheels made of phosphor bronze very advantageous, and in the end economical. A mild cast-steel wheel also gives very good results; malleable cast iron, although found to vary considerably in its quality and fibre, and consequent resistance to stress, is much to be preferred to ordinary cast iron. In small wheels and pinions where additional strength is necessary the teeth should be 'shrouded'—that is, the teeth are all joined together by a rim of metal at their outside periphery, which will add to their strength some 40 per cent. or more. When large power has to be conveyed directly from one shaft to another in close proximity, mortise or cog wheels can be used with advantage if the speed required is not too great. Wooden cogs should be about one-third thicker than the iron teeth of the wheel with which they are engaged, they should be made somewhat shorter and thicker at the root of the tooth than ordinary wheels. Care should, however, be observed in shortening the teeth that the arc of their contact is not too much reduced. In practice involute teeth are found stronger than cycloidal.

The shorter teeth are in moderation, and the thicker they are at the root the more stress they will bear. In cycloidal teeth it may be taken as a safe rule that the flanks of the teeth should never be described with a rolling circle the diameter of which is greater than half the diameter of the pitch line inside which it is rolled, and it is found that the smaller the diameter of the describing circle used for the flanks the stronger the teeth are. For high-speeded machinery, where the stress and friction are excessive, toothed wheels should be made about one-third wider on the face than for slow-running machinery; so that the contact of the teeth may be spread over a considerable surface, enabling them to resist successfully the increased stress. Care should be taken, however, that the teeth are not allowed to slide one against the other. All toothed wheels—say, under 18 inches diameter—where the stress is very severe, such as the intermediate feed gear of planing and moulding machines, we recommend to be made solid. We ourselves have used phosphor bronze for this purpose, and have found the vibration lessened and consequent wear of the wheel much improved. In America with machines of this class it is the practice to make the intermediate gear to work expansively, thus allowing the upper feed rollers to adapt themselves to the irregularity of the timber. This plan lessens the strain considerably, and is a decided improvement on fixed gearing. In comparing belt with toothed gearing for transmitting power, the balance, except under especial circumstances, is in favour of the former, as belt gear requires less motive power to transmit the same effective force; it is also conveyed more evenly and with less noise and vibration, especially if the gearing is at all worn or badly proportioned.

CHAPTER XXXVI.

BELT GEARING.

THE belts employed for driving wood-working machinery should by preference be made of leather, except when used out of doors or where likely to be wetted, when the use of vulcanised indiarubber or indiarubber cloth is advantageous. They are sometimes made of other materials, such as cotton; and recently, at the International Exhibition held in Paris (1878), a belt made entirely of paper supplied motive power to some twenty wood-working machines. This belt was manufactured by an American firm, and was known as Crane's patent Japanese paper belt, and after twelve months' wear it appeared in capital order. It is claimed for these belts that they are less in first cost and wear longer than leather. This, however, we are not in a position to verify.

In 1853 Mr. W. Paxton of Johnstone, introduced driving bands composed of a series of cylindrical cotton bands or cords attached together, side by side and rolled flat, giving to the finished band a transverse section similar to that of leather. This form of band should possess a large amount of driving power and be suitable for moderate speeds.

Leather, from its strength, pliability, and durability, is up to the present the best known material to employ for all ordinary machine bands, but for extra-wide main driving belts vulcanised indiarubber is used and preferred by many. It has the advantage over leather of lower first cost and greater driving power; but it is a moot question, considering the difficulty of repairing by unskilled labour and other points, which in the long run is most economical to use. For narrow belts, or belts that are obliged to be run at short centres or high velocities, engendering a considerable amount of heat, our opinion is 'there is nothing like leather.'

We have seen in use some of Gandy's patent driving belts, made of American cotton, which was folded and sewn together longitudinally, and saturated with some oily composition, which renders them proof against water or change of temperature. In joining them transversely the ordinary jump-joint, sewn with laces, was used. They appeared to run true and grip the pulleys well; but as to their wearing capabilities we are not in a position the speak. From tests made by Kirkaldy, of London, their breaking strain, as compared with leather, is very high. Experiments were made on belts of 6 inches in width, with the following results:—Best ordinary leather, breaking strain 6,299 lbs.; Helvetia leather, 7,522 lbs.; eight-ply American cotton, 11,763 lbs. As these cotton belts are produced at a considerably lower first cost than leather, we purpose taking an early opportunity of testing their suitability for driving high-speeded machinery.

In calculating the transmission of speed by means of belts allowance must always be made for the 'slip' and deviation of the belt, but more especially in connection with wood-working machinery; running, as it does, at high speeds, oftentimes at short centres and over small pulleys, in the midst of dust, which renders the leather less pliable, the 'grip' or driving power of the belt is considerably lessened.

The strength of the best ox-hide belts used for belting has been calculated at about 3,086 lbs. per square inch of section. This is reduced at a riveted joint to 1,747 lbs., and to 960 lbs. at a laced point. One-third of these figures may be given as a safe-working tension. As belts, however, vary much in thickness, the following table in lbs. per inch width of safe-working tensions may be of use:—

Thickness of Belt	Working Tension	Thickness of Belt	Working Tension
In.	Lbs.	In.	Lbs.
$\frac{3}{16}$	60	$\frac{1}{2}$	160
$\frac{7}{32}$	70	$\frac{9}{16}$	180
$\frac{1}{4}$	80	$\frac{5}{8}$	200
$\frac{5}{16}$	100	$\frac{11}{16}$	220
$\frac{3}{8}$	120	$\frac{3}{4}$	240
$\frac{7}{16}$	140		

For transmitting power in high-speeded machinery belts should be made about one-third wider than is found necessary in machines running at a slow speed, and the smooth side of the belt should run next the face of the pulley. All belts should be made even in thickness and neatly joined, and the driving pulleys accurately turned and rounded on face, or some difficulty will be found in making the belts run true. Twisted belts should be avoided as much as possible; but if it is found necessary to connect by belts shafts that are not parallel, care should be taken that the belt should always be in the plane of rotation of the pulley to which it is approaching, without regard to the retiring side, which may be deviated from that plane without affecting the belt. If this rule is borne in mind, little trouble by belts running off the pulleys will be experienced.

When belts are required of a greater width than 9 inches, a double belt is preferable to a single one and is found to run truer.

As regards joining belts, hooks, malleable toothed plates, and numerous other plans have been introduced. Many users, however, still prefer the ordinary plan of lacing. We have found the double I belt-fasteners, known as Green's patent, to be both expeditious and economical, especially for narrow belts, where the tensile strain is not great.

We have recently seen some endless driving bands formed of crucible steel wire woven into a network or chain. The wires are arranged to run parallel to the width of the belt, and possess great flexibility and driving power, and will run with ease round the smallest pulley. As regards their economy in wear, we cannot speak from experience. These bands are also constructed with a leather or elastic lining, to prevent stretching, which plan we should think would be an advantage, at any rate for high-speeded machinery, as the friction engendered by the steel wire on the cast-iron pulley would be considerable, and the consequent breakage of the wire from expansion and contraction must be looked for. The use of metals for driving bands is not, however, new, as in 1856 the Earl of Caithness took out a patent for constructing driving bands out of sheet metal, such as iron, steel, brass, or composition metals.

The following 'hints,' taken from the 'Textile

Manufacturer,' may be found useful to users of machine bands:

Belts stuffed with tanner's dubbin on the flesh side will become as smooth all over as the hair side, and will outlast six belts which are run on the hair side exclusively.

'Three times the adhesiveness is gained by softness and pliableness of belting leathers over those which are dry.

'Long belts are preferred to short ones, but care must be taken that the length be not too great.

'Horizontal, inclined, and long belts give a much better effect than vertical and short ones, and those that have the driving side below than otherwise.

'Belts of coarse loose leather will do better service in dry, warm places. For wet or moist situations the finest and firmest leather should be used.

'Experience says, the hair side of a belt put next to the pulley will drive 34 per cent. more than the flesh side.

'The strongest part of belt leather is near the flesh side, about one-third the way through from that side.

'Leather belts must be well protected against water, and even moisture.

'Short belts require to be tighter than long ones. A long belt, working horizontally, increases the tension by its own weight, acting in the curve formed between the pulleys.

'Sufficient care is seldom taken to let belts run free and easy, and it has been one of the greatest errors, more or less prevalent in all large factories, to run the belts so tense as greatly to injure them and rapidly increase the wear of the bearings.

'In many instances the tearing out of lace-holes is often unjustly attributed to poor belting, when in reality the fault lies in having a belt too short, and trying to force it together by lacing; and the more the leather has been stretched while being manufactured, the more liable it is to be complained of.

'To obtain the greatest amount of power from belts the pulleys should be covered with leather: this will allow the belts to be run very slack, and give 25 per cent. more durability.

'A careful attendant will make a belt last five years which, if neglected, might not last one.

'It has been found in practice that belts must not run faster than 30 feet per second, nor have a tension of above 300 pounds per square inch of section.

'The friction of a belt is double on wood what it is on cast iron.

'Long belts are less liable to slip than short ones.

'The softer woods are better for pulleys than the harder kinds, but pear wood and nut tree are best for cord-wheels. Grease must not be put on wooden wheels on which belts run.

'Tightness by tightening pulleys must be applied to the slack side of belts.

'The belts should be cut from the centre of the skin.

'Thickness of belt does not always give strength.

'If too great a distance is attempted, the weight of the belt will produce a very heavy "sag," drawing so hard on the shaft as to produce great friction in the bearings, while at the same time the belt will have an unsteady flapping motion, which will destroy both the belt and the machinery.

'The connected shafts should never, if it can be avoided, be placed one directly over the other, as in such case the belt must be kept very tight to do the work.

‘It is also desirable to locate the shafting and machinery so that belts shall run off from each other in opposite directions, as this arrangement will relieve the bearings from the friction that would result were the belts all to pull one way on the shaft.

‘If possible, the machinery should be so planned that the direction of the belt motion shall be from the top of the driving to the top of the driven pulley.

In punching a belt for lacing, it is desirable to use an oval punch, the longer diameter of the punch being parallel with the belt, so as to cut out as little of the effective section of the leather as possible.

‘Begin to lace in the centre of the belt, and take much care to keep the ends exactly in line, and to lace both sides with equal tightness. The lacing should not be crossed on the side of the belt that runs next to the pulley.

‘Never add to the work of the belt so much as to overload it.

‘A good leather belt, 1 inch wide, has sufficient strength to lift 1,000 pounds.

‘*Waterproof Glue.*—Fine shreds of indiarubber dissolved in a warm copal varnish make a waterproof cement for wood and leather.

‘*To Preserve Leather from Mould.*—Pyroligneous acid may be used with success in preserving leather from the attacks of mould, and is serviceable in recovering it after it has received that species of danger, by passing it over the surface of the hide or skin, first taking due care to remove the mouldy spots by the application of a dry cloth.

'*Castor Oil as a Dressing for Leather.*—Castor oil, besides being an excellent dressing for leather, renders it vermin-proof. It should be mixed—say, half and half—with tallow or other oil. Neither rats, roaches, nor other vermin will attack leather so prepared.

'*How Glue should be made to Fasten Leather to Iron, in order to cover Iron Pulleys.*—1 part of crushed nut-galls is digested 6 hours with 8 parts of distilled water and strained. Glue is macerated in its own weight of water for 24 hours and then dissolved. The warm infusion of galls is spread upon the leather, the glue solution upon the roughened surface of the warm metal; the moist leather is pressed upon it and then dried. Use wider belts or larger pulleys if the adhesion is insufficient. It is a good plan to wash the worn surface of *rubber* belts with soap and water.'

CHAPTER XXXVII.

WOOD.

In a work of this class it may not be out of place to notice briefly the woods which are chiefly converted by machinery into articles of daily commerce.

Resinous woods are those most chiefly used, foremost amongst which is the red or yellow pine, the best of which comes from the north of Europe, notably the Riga, Norway, and Memel. These trees are felled without discrimination, the best timber being selected for deals, and the remainder being converted into battens, mining timber, poles, fire wood, &c. When used as beams, fir should be sawn longitudinally to test its soundness. For mouldings and joiners' work seasoned American white or yellow pine is well adapted. The best is shipped from Quebec. A large quantity of pine of good quality, generally known as Board and Waney pine, is shipped from various Canadian ports.

Norway spruce or white deal is chiefly used for poles, ladders, and masts. Russian red wood is used for lath wood in large quantities. Canadian pitch pine is chiefly used for deck planking or conveying water. The whole of the varieties of the Pinus family are easily converted by machinery. When sawn, saws with large teeth and coarse pitch should be used. The ordinary gullet or briar tooth is as suitable as any. In sawing pitch pine a coarser set must be put on the saw, owing to the increased friction arising from the tenacious, clinging properties of the resin. The saw blade should also be well greased.

Amongst the other resinous woods must be mentioned cedar. This wood is largely used for cabinet work. It is grown chiefly in Spain and the Levant. Red cedar is a native of the West Indian islands and North America. This wood is even in the grain and readily worked, but is apt to split unless care is taken; for cutting cedar, a saw with a moderately fine gauge, pitch, and space should be used. We have found a peg-toothed saw very suitable.

Amongst the hard woods generally used oak, mahogany, ash, elm, teak, and walnut take first rank. Oak is the most durable of all woods, and one of the hardest. English-grown oak is unequalled for strength and durability, but fine oak timber is also imported from Russia and America.

Mahogany is much used for all kinds of furniture work. It is obtained chiefly from Domingo, Honduras, and Cuba. English ash is chiefly used in wheelwrights' and agricultural implement works. It is long in the grain and very tough and elastic. English elm is hard and tough, and difficult to work. It stands well in water, and is used considerably in ship-building, pump-work, wheelwrights' work, &c. In sawing these woods the gullet or mill-saw teeth, arranged with a diminished space and nearly upright pitch, should be used. Beech should not be used for work exposed to air and moisture, as it will rapidly deteriorate. For tropical climates fustic is found to stand well. Various processes of seasoning wood by desiccation and other means have been tried, but nothing is found equal to the exposure of the wood to the atmosphere. When used for interior work, it should be kept for at least three years. Wood suffers decomposition from excessive heat, or if exposed to a humid atmosphere; but if buried, and the air entirely excluded, its decomposition is slow. Dry air does not seem to affect it.

The proper time and manner of felling trees, when they are at their prime for conversion, is a special business, and requires a special knowledge, that can only be gained by experience. In most timber-producing countries trees of all sizes are at present felled indiscriminately, but this pernicious system will doubtless in the course of years have its effect. We need hardly say that any tree showing incipient signs of decay should be immediately felled, as its commercial value will then rapidly decrease. The proper time for felling trees depends in a great measure on their genus; winter or summer is generally to be preferred, the timber being then less full of sap. Resinous trees are best felled in summer, other trees in winter, except oak or those from which the bark has to be stripped, in which case early spring is found the most suitable, as the bark will then peel most easily. The bole of the tree should always be severed as near the ground as possible. Although several attempts, with more or less success, have been made to fell trees by mechanical means, the difficulties of situation, transport, and economical manipulation have hitherto prevented much progress being made in thus superseding the art of the woodman. From experiments it has been found that the wood immediately surrounding the heart of the tree is the weakest, and this weakness increases with the age of the tree. The woody fibres next the bark are also weaker than the rest, the strength of the timber gradually increasing from the heart outwards. Moisture in timber weakens it considerably, and its crushing resistance is found to be little more than one-half of what it is when dry.

Experience, of course, can be the only sure guide as to the condition, strength, or value of timber; ill-conditioned timber can, however, generally be distinguished by a looseness and woolliness of the fibre and a clogging of the teeth of the saw; when cut it also presents a white, floury appearance. The timber used for joinery purposes and conversion into mouldings, &c., should be as sound and dry as possible. If it is necessary to season the timber artificially, what is known as the hot-air method is generally considered the best. This consists in confining the timber in a chamber, and subjecting it to a current of hot air forced through the chamber by means of a fan. It is necessary to vary the temperature of the hot air according to the kind and size of timber. The following have been found the most suitable drying heats:—

Oak, the temperature should not exceed	105°	Fahr.
Leaf woods	90° to 100°	,,
Fine woods, in deals and upwards .	120°	,,
,, in thin boards	180° to 200°	,,
Mahogany do. .	280° to 300°	,,

CHAPTER XXXVIII.

CIRCULAR AND STRAIGHT SAWS.

In connection with the productive efficiency of wood-working machinery the proper selection, sharpening, and manipulation of the cutting tools employed is a point of the utmost possible importance, as, no matter how well designed or constructed a machine may be, unless the tools employed are exactly suitable to the work to be performed, are made of material of the highest quality, and are tempered and sharpened to the most correct cutting angle, the production of the machine is in every way unsatisfactory, the work turned out being less in amount and the quality inferior, whilst the force expended to produce it is greater.

As being the most general and important cutting instrument employed in the conversion of wood, we will first consider the saw. Saws may be divided into three classes—viz. (1) reciprocating or mill saws, (2) rotary or circular saws, (3) endless band or ribbon saws. Another form of saw is known as the cylinder saw, but this form is rarely used. On the gauge, shape of tooth, and 'set' of the saw best adapted to perform certain work a great diversity of opinion exists, English, Continental, and American practice on these points differing considerably. No fixed rule can, however, be laid down, as all these points must depend on the nature, quality, and condition of the material operated on. An immense variety exists in the shape of the teeth employed; the best known are the peg, gullet, fleam, mill saw, hand saw, hog mane, dog, parrot bill, bird tail, hook, and American tooth. The first four mentioned are those chiefly employed in this country. In cutting or ripping with a circular saw soft woods, such as pine, with the grain of the wood, the teeth of the saw should be set farther apart, and the pitch or rake and set of the teeth should be considerably coarser than for hard wood. If a line is drawn through the points of the teeth the angle formed by the face of the tooth with this line should be, for cutting soft woods, about 65° to 70°, and for cutting hard woods about 80° to 85°. The angle formed by the face and top of the tooth should be about 45° to 50° for soft wood, and 65° to 70° for hard. It will thus be seen that the angle of the tooth found best for cutting soft wood is much more acute than for hard; these figures are, however, given approximately, and should be modified according to circumstances.

The action of the saw when operating with the fibre of the wood may be regarded as chiefly a splitting one, the revolving saw-teeth acting like a series of small wedges driven into and separating the longitudinal fibres of the wood.

Some saw teeth of American origin are very extraordinary in form, and the advantages gained by thus shaping them are not always obvious.

Mr. Peter Cook, an American, took out a patent some twelve years since for improvements in the shape of saw teeth. According to this invention the teeth are made of a rectangular, or nearly a rectangular, form, the tops of the said teeth being bevelled to form a cutting edge throughout their entire length. The cutting edge of each tooth coincided with the line of motion of the saw, and such cutting edge may be of equal length to its base. The bevel of each tooth was on the opposite side to the next one, and the teeth may be set in the ordinary way, the set or deflection being on the opposite side to the bevel of the tooth. If desired the ordinary clearing tooth may be employed at suitable intervals along the saw. The principal advantages claimed to be derived from this construction of saws are smoothness left on the cut surfaces of the wood, the freedom with which they pass through the material operated upon, and the capability of cutting equally well in both directions.

We may here remark it is of the greatest importance that the steel used for the manufacture of saws and cutters should be of the highest possible quality; any advantage that may be obtained in lower first cost in purchasing a second quality is immediately thrown away in extra loss of time in sharpening, inferior work, &c.

In sawing resinous woods, such as pitch pine, the teeth of the saw should have a considerably coarser 'set' and space than for hard woods. For sappy woods saws with longer and sharper teeth should be used.

Before sharpening a circular saw it should be made perfectly round; this can best be done by placing the saw on the spindle and running down the points of the teeth by means of a hard piece of stone. It is important that the cutting angles and the tops and faces of the teeth should be bevelled exactly alike; the gullets, too, should be of even depth, as the saw will work more freely and with less power than if the teeth are allowed to get short and stumpy. The use of a revolving emery disc for saw-sharpening and gulleting has the additional advantage of doing away with the old-fashioned plan of punching out the teeth, which generally springs the saw plate and necessitates the re-hammering of the saw. In the manufacture of saws the steel plates used are hammered true, which is an operation requiring a considerable amount of skill to perform properly, and afterwards ground on a face plate. We have recently seen working some circular saws of American manufacture, which, we were informed, instead of being hammered were pressed true by machines of immense power. They certainly performed their work very cleanly and with a minimum amount of friction. If the process of hammering can be dispensed with in favour of some mechanical method, the result should be in every way advantageous, as the saw would run truer and with less power, the indentations necessarily left in the saw from hand hammering, notwithstanding the grinding process, being entirely done away with. In working circular saws successfully, in addition to the shape of teeth most suitable to the work, the gauge of the saw, and the speed, much depends on the efficient 'packing' of the saw blade. In America, where timber is plentiful, little is done in this direction; the consequence is saws of much stouter gauge have to be used, resulting in a consequent loss of power and material. Considering the great progress in wood-working machinery, we cannot conceive how American engineers still adhere to this very wasteful conservatism. The plan for guiding the saw generally pursued in this country is to screw pieces of wood--mahogany is suitable, as it retains well in its fibres any lubricants employed—to the 'finger plate' and below the saw table on either side, and running immediately parallel and close to the saw; the wood is rebated to allow hemp, gasket, or other fibrous material charged with lubricating matter to be packed in tightly to lubricate the saw, which is especially necessary when sawing hard or resinous wood. This method of packing was introduced by Holland about the year 1842, and has been in use ever since. Some makers construct especial packing boxes for holding the oily material, so arranged that it can be replenished with oil as required. To ensure steadiness in running and prevent 'buckling,' saws should be packed at both the back and front. A plan of 'packing' pursued by M. Arbey, of Paris, and shown by him in the International Exhibition of 1878, is deserving of notice. On either side of the saw, and let into the top of the bench, were fitted transversely four set screws, which were adjustable to the gauge of the saw. Into the centre of each of these screws was fitted a piece of hard wood, which, when the screws are tightened up, presses against and guides the blade. Exhibited also in the French section by Messrs. Gérard, of Paris, was Ganne's patent saw guard and guide. This consists of a narrow cast-iron box made in the form of a half-circle, inside which the periphery of the saw runs. This box or chamber is suspended over the saw from an arm fitted to one side of the saw-bench framing, and is made adjustable to saws of varying diameters. Set screws fitted through the box on either side of the saw act as guides.

In packing circular saws care should be taken, when oiled gasket is used, that it is fitted evenly on either side of the front half of the saw, so that the friction and consequent expansion and contraction of the saw blade may be perfectly uniform. These small points are, however, often neglected, the result being that the saw, especially if of thin gauge, runs out of truth without any apparent cause. Other reasons there are, however, which cause saws to run out of truth, amongst which may be named saws of too thin a gauge for the work, irregular setting or improper form of tooth employed, insufficiency of clearance for sawdust, too rapid a feed, or a saw blade of too mild a temper.

For all ordinary purposes of sawing the gauges given herewith will be found suitable; but for special purposes, or special kinds of wood, they can be increased or decreased, as experience directs.

Diameter of Circular Saw in Inches	B W. Gauge	Diameter of Circular Saw in Inches	B W. Gauge
12	17	50	8
14	17 t	52	8
16	16	54	7 e.
18	15	56	7
20	14	58	6
22	14 t.	60	6
24	13	62	6
26	13	64	6 f.
28	12	66	6 t.
30	12	68	5
32	12	70	5
34	12 t	72	5
36	11	74	5
38	11	76	5
40	11 t	78	5
42	10 e.	80	5 f.
44	10	82	5 f.
46	9 e.	84	5 f.
48	9		

t. signifies tight, e. easy, f. full.

The straight or mill-saw webs used in machines with a reciprocating motion can be worked of a much thinner gauge than circular saws. For ordinary use the following are suitable:—

Saws up to 3 feet 6 inches long, 16 gauge.
Saws 4 feet long, 15 gauge full.
Saws from 4 feet to 5 feet 6 inches long, 14 gauge.
Saws 6 feet long, 14 gauge full.
Saws from 6 feet 6 inches to 7 feet long, 13 gauge.

As regards sharpening and setting the teeth of saws, much has been written; the usual practice is to bend by means of a saw-set the teeth alternately to the right and left. Many practical men prefer to set their saws by means of a blow given by a hammer or punch, as the teeth stand to their work better and require less frequent setting, it being found, especially with thin-gauge saws, that the teeth have a constant tendency to assume their original position. In setting saws of a stout gauge and hard temper with a hammer, considerable care must be exercised to prevent fracture; the best plan we are acquainted with for setting circular saws is to fit the saw horizontally on a stud fitted in a wooden frame having a transverse movement. A small steel anvil with a bevelled face should be placed at one end of the frame, and the saw traversed backwards or forwards for the teeth to overlap the anvil centre the distance of the set required. For setting a series of smart light blows in preference to one heavy one should be given, and the teeth set a little coarser than is absolutely required in work. Some users file and set the teeth of their circular saws in triplets, the first tooth with a bevel to the right—the second remains straight—and the third with a bevel to the left. We are at a loss to see, however, any especial advantage in this plan. Occasionally also saws are used with the body of the blade deflected from the plane of its cutting edge. This plan is said to give greater stiffness and increased cutting power to the saw. In America many saws are constructed with false teeth, dove-tailed into the periphery. The advantages claimed for this plan is that the teeth are easily renewable when worn out, and that the centre of the saw may be made with a steel of inferior quality. A somewhat novel method of inserting false saw teeth has recently been patented by Mr. Frederick Schley, of New York. It consists of a circular holder made in two parts, hinged together, grooved around its edge, and fitted to a circular notch at the root of the saw tooth. The saw plate is made with a V-shaped edge, which fits the periphery of the holder. A space is left between the hinged portions of the holder to receive the tooth, and there is a notch for receiving the small projection at the root of the tooth. This prevents the tooth from drawing out, and it is prevented from lateral motion by a groove in the tooth and a V-shaped edge on the holder and saw plate. Much ingenuity has been expended in this direction, but we are at a loss to see any particular advantage when we consider that with false teeth it is necessary to use saws of stouter gauge, the friction in using is greater, consequently the power required to drive is more. They are seldom, if ever, used in this country; their use being almost entirely confined to the United States. To lessen the labour in gulleting, circular saws are sometimes made with a series of round holes punched through the plate from the root of the gullet towards the centre of the saw; this certainly lessens considerably the labour required in sharpening, especially if done by hand, and should prevent expansion, but we should imagine the friction must be somewhat increased. Where many thin boards of valuable woods have to be sawn on a saw bench, 'ground-off' saws—that is, those which are bevelled on the one side, i.e. the gauge reduced from near the centre to the periphery—should be used.

Cross-cutting saws, or those used for severing the fibres of the wood transversely, differ essentially in the forms of the teeth employed and the method of sharpening. The fibre of the wood, when severed across the grain, is comparatively unyielding, and the teeth of the saw meet with much more resistance, and it is found necessary to make the teeth considerably more upright, and more acute or lancet-shaped in their form, than for cutting with the grain. The faces of the teeth should be sharpened to a keen edge, and for hard wood filed well back, so that in work they may have a direct cutting action, similar to a number of knives. Care should also be taken that the teeth are made of sufficient depth to afford a free clearance for the sawdust.

Most of the points to be borne in mind as regards the shape, pitch, and set of the teeth of circular saws apply equally well to straight saws with a reciprocating motion. In these machines, owing to the slower rate of feed and the number of blades employed, saws of a considerably thinner gauge can be used. A considerable saving in power and material is thus effected. Reciprocating saws with a double cut—that is, one-half of the saw teeth were included in one direction from the centre of the blade, and the other half in the opposite direction—were invented some years since by a Mr. J. Davis.

Mill-web saws are in America occasionally made in sections, and a patent for improvements in this direction has recently been taken out by Mr. C. H. Hubbard, of Pittsburg. His improvements consist in forming the saw in sections arranged longitudinally, edge to edge, the front section being the cutting edge of the saw and the back section a plain blank. By this arrangement it is claimed that a much narrower cutting section is used, thus reducing the friction and the first cost of the blade, and also allowing it to be more easily tempered or removed from the frame without disturbing the strain of the blank sections, which can be used with other sets of cutting sections.

All mill-web or straight saws, either long or short, should be ground thinner towards the back of the saw. Care should be taken that they are made perfectly true, and flat and uniform in toothing and temper.

Saws formed in this fashion require less set, and work with considerably less friction; their first cost, however, is slightly increased. In fixing straight saws in their swing frame, care should be taken that they are arranged with the amount of 'lead' or 'rake' best suited to the wood they are intended to cut. In sawing some classes of green timber, in which the fibres are long, considerable trouble is sometimes experienced in preventing them clinging to and so increasing the friction of the saw that it becomes more or less choked and the blade 'buckled.' To obviate this Mr. Thomas Greenwood, of Leeds, proposed some years back so to construct the frame that the saw blades were drawn back after the completion of each stroke, so that the saw teeth might clear the wood during the ascent of the swing frame. This could possibly be put into operation with large frames ru [illegible] low speed, but would be practically impossible with the light high-speed frames of the present day. If a large number of saws are employed we can recommend the use of a series of circular revolving opening wedges and saw teeth of extra-coarse space and pitch.

We give as a Frontispiece a plate of various forms of saw teeth taken from Worssam on 'Mechanical Saws.' A considerable number of these teeth, however, are rarely used, and we are at a loss to see the advantages of some of the more complex forms sometimes used on the Continent and in America, as the extra expense of keeping them in a satisfactory working condition would more than counterbalance any supposed advantage. The faces, backs, or tops of the teeth shown in the plate are expressed in angular degrees, measured from a line running through the points of the teeth. The angle of the point itself is found by subtracting the angle of the back from that of the face of the tooth, or the less from the greater of the first two numbers. The diagrams are not drawn to any definite scale, being given to illustrate the forms of teeth and not the dimensions or gauges, which it is necessary to vary considerably according to the nature or condition of the wood being operated upon.

CHAPTER XXXIX.

BAND OR RIBBON SAWS.

MUCH advance has been made of late years in the manufacture of band or ribbon saws, but chiefly by France, which supplies almost entirely the rest of the world. This arises not so much from the quality of the steel employed—which, we believe, comes from England—but from the peculiar method employed in tempering, which ensures to the blade a considerable amount of hardness combined with toughness. The manufacture of these saws on an extensive scale has never been carried out in this country, the method of tempering successfully being kept more or less a secret. Band-saw blades, when in operation, are subjected to several strains, the chief of which is a bending or torsional strain, which in heavy work with sharp curves is very severe. In addition to this the expansion and contraction in the blade engendered by the friction whilst in use, seems in a great measure to alter the fibre or granular structure of the steel, and the consequent breakages have militated much against the universal adoption of this method of sawing. The writer some time since tried a plan of making half of the saw blade carrying the teeth of a hard temper, whilst the back of the blade was left soft. This, however, owing

CHAPTER X

CUTTERS.

THE action of revolving cutters, such as those used in planing and moulding machines, is similar to that of circular saws. For planing soft wood the bevel of the cutting edge of the iron should be more extended than when used for hard wood. About 25° to the face of the iron is the best angle, whilst for hard woods about 40° is found most suitable. They are occasionally worked at a more acute angle than this, but in working very hard woods the edges of the cutters are more liable to break. Cross-cutting cutters, such as those used in tenoning machines, should be arranged to work diagonally to the grain of the wood. An angle of about 15 degrees to the axis is usually found suitable for soft wood, as it is found the nearer they act with the fibre of the wood the smoother the work. Cutters for tenoning machines are made by some engineers slightly helical. We think, however, that anything gained in this manner is more than lost in the extra trouble involved in keeping them in order, as well as increased first cost. For planing wide surfaces M. Arbey, of Paris, has for some years used the spiral or twisted irons patented by Mareschal and Godeau. The advantage claimed for this form of knife is, that the pitch of the knives is so arranged that the end of one comes opposite to the beginning of the other, thus giving a continuous cut during the whole revolution of the cutter block. As part only of the whole length of the knives strikes the wood at the same time, the jar or vibration is thus considerably lessened; and, as they always present the same cutting angle to the wood, cross-grained and knotty stuff can be worked. The knives used are very light, being from one to two millimetres in thickness. They are, however, more difficult to manage than straight knives, and require considerable skill and care in keeping them in order; hence their very partial adoption. Where this form of knife is adopted an arrangement is generally made to sharpen them in their places on the cutter blocks by means of a revolving emery wheel. Whatever form of knife is used, the steel employed in its manufacture should be of the highest obtainable quality. We prefer cutters made of wrought iron faced with steel to those of solid steel, as being easier to work and less liable to fracture. In establishments where a large variety of woods are worked it is advisable to have several sets of knives ground to the various bevels found best suited to the work. Much has been written as regards tempering cutting tools. No absolute rules, we think, can be laid down, at any rate as regards wood-cutting tools; it simply resolves itself into a matter of practical experience. For working soft woods with knives of an acute bevel a light straw-colour temper is suitable, whilst for harder woods, where the bevel of the knives used is made more obtuse, the temper should be made slightly harder in proportion. Cutters should always be ground with a double bevel, leaving at the cutting edge, say, about $\frac{1}{8}$ in. to be whetted with a stone to a keen edge by hand. Several varieties of stone are suited to this purpose, but we have found nothing better than a good Turkey stone. All plane irons above 12 inches long should be ground in a sliding frame, fitted with adjustments for any desired bevel, as it is impossible to keep long irons, such as those used in panel-planing or trying-up machines, true with hand grinding against an ordinary fixed rest. In panel-planing or other machines for working wood of considerable width, instead of using two long planing irons extending the whole width of the machine, eight short ones should be arranged in succession, two on each of the four sides of the cutter blocks; this plan, although causing a little more trouble in adjusting the irons, does away with the difficulties often experienced in keeping irons of very great width in a satisfactory condition.

In constructing moulding irons, a plan often pursued, but still essentially wrong, is to cut the shape of the required moulding on the edge of the steel and grind a bevel backwards from it. The result is the exact profile of the moulding is constantly liable to be altered when sharpening. In place of this the form of moulding should be always milled into the face of the cutter itself, as it thus, if sharpened to the proper bevel, retains its true form. A few years since a somewhat novel system of steel cutters for working wood was patented by M. Guilliet Perreau, of Auxerre, France. He claimed that in his cutters, when the profile of the moulding was once formed it was unalterable, no matter how badly the sharpening might be done; that they made a cleaner cut and were less liable to accident. We have seen this form of cutter in operation in various machines and giving very satisfactory results. They are made from one piece of steel, in form something like a deep saucer; the periphery is shaped to the profile of the desired moulding, and has several openings, which are sharpened towards the centre and present as many cutting edges to the wood. These cutters can be modified in shape for tenoning and other operations; they possess several features of value, but, unless manufactured on a considerable scale and with special appliances, their first cost would be considerably in excess of the ordinary form.

Fixed cutters for planing machines should be fitted with back irons, and the cutting edge arranged at a slightly oblique angle to the wood, as the shock on the knife is thus received gradually. This also applies to veneer-slicing machines when a sliding cutter-block is used, except in some kinds of wood where it is found necessary to cut the fibres of the wood the whole width of the board or block at the same moment.

In establishments where a considerable number of moulding irons are in use, some half-dozen stones of fine grit should be mounted and turned up to fit the rounds and hollows of the most usual form of irons, which can thus be sharpened without the aid of hand filing, which is an expensive method and deteriorates considerably the cutting power of the steel, from the constant softening and hardening processes through which it has to go.

In surfacing and squaring-up machines, where cylindrical gouges are used, especial care must be taken that they are set at the most suitable angle required by the nature of the wood, and that the temper of the gouge is not made too high, or fracture and consequent loss will be the result. We have found the palest of pale straw colour the best suited, except for the hardest class of wood ; a considerable increase in the strength of the steel is produced by hardening in oil.

CHAPTER XLI.

BAND-SAWING MACHINES FOR HEAVY TIMBER.

DURING recent years the introduction of band-sawing machines for converting heavy timber has made very considerable progress, more particularly in America, where a great number of machines of the largest size are in operation. When we consider that a well-constructed band-sawing machine will convert logs of the heaviest class with considerable rapidity, and at the same time effect a great saving in power and wood, it is somewhat remarkable that their development for log sawing has not been more rapid. This may be to a certain degree attributed to the difficulty there used to be in obtaining band-saw blades of the necessary width and temper to withstand the very considerable strain to which they are subjected, and to the want of provision of adequate means of keeping the saw in a true vertical line. These difficulties have now been entirely overcome, and the machine made commercially successful. The object of the present chapter is to consider briefly some of the points to be desired in the construction and working of a machine of this class.

MAIN FRAME.—In designing the main frame or column of the machine, strength with rigidity in working must be secured. In the best practice a hollow-cored or box casting made in one piece and arranged with an extended base is usually employed, although some American manufacturers prefer a wrought-iron girder column bolted on to a heavy base plate. Whichever is used it is important that the base plate and foundations generally are sufficiently massive to absorb the vibration of the machine when working at its full speed. The base of the machine is fixed below the mill floor, and the foundation bolts pass entirely through the masonry. As regards the foundations, dressed stone is best, as it offers a better resistance than brickwork. It should be accurately levelled, laid on a bed of concrete, and set as nearly perpendicular to the direction of the stress as possible. The quality of the work turned out and the longevity of high-speeded machines depend more on the stability of the foundations than is generally imagined, and any reasonable outlay in this connection is usually money well invested. With the object of securing increased steadiness in operation we have seen machines working with success in which the upper saw spindle runs in bearings fixed on the top of the column and the lower spindle in a vertical line beneath the base of the machine. An additional pair of bearings placed outside the driving pulleys of the bottom spindle to withstand the pull of the belt are an advantage.

Band Saw Wheels.—Perhaps the most important features in the construction of a band-sawing machine are the saw wheels. These should combine in the highest possible degree strength with lightness; this is more particularly the case with the upper saw wheel, as should it be too heavy it may overrun the bottom or driving wheel, and be a fruitful cause of the breakage of saws.

The wheels should be made of wrought iron or steel, covered with wood at the periphery, and this again covered with a band of vulcanised india-rubber or leather. The wheels should be turned all over, the top wheel mounted elastically, and both be *perfectly* in balance. Should they be the least out of balance the consequent centrifugal force causes a constant jumping motion on the wheels, which will ultimately break the finest saw blades. For log sawing the saw wheels must of necessity be of large diameter—in fact, within moderation, the larger the better—as, should the arc of contact of the saw with the wheel be too acute, the blades are rapidly cracked and fractured. The diameter of the wheels should be in proportion to the thickness of the log sawn, varying from 6 ft. to 12 ft. diameter, by about 8 in. on the face. It is difficult to formulate a rule on the subject, but a wheel of, say, three times the diameter of the thickness of the wood to be sawn will generally be found to be suitable. The top saw wheel must be arranged to cant, so as to direct the saw blade to any desired point on the face of the wheel, and so equalise its wear; care must be taken, however, that the teeth are not allowed to run so far in as to tear the covering. The outside india-rubber covering should be a flat ring about 1 in. thick, sprung on and carefully cemented in its place. If leather is used, two thicknesses, one of sole and one of buff leather, can be recommended; these will require rivetting in their places.

The saw wheel spindles should be of steel supported by two pairs of bearings to each spindle; these can be mounted in an adjustable slide for the top wheel and in standards or pedestals for the bottom wheel. We have found this arrangement much preferable for heavy machines to the plan of mounting the wheels to run on studs, or using single bearings or bushes. The top wheel spindle and slide must be capable of being adjusted vertically to suit saws of various lengths; this can be secured by means of a hand wheel and screw working into a gun-metal nut fitted in the slide casting. For covering the wheels with wood—which should be hard and well seasoned—ash or walnut, about 2 in. thick, is suitable; it should be accurately sawn in segments, lap-jointed, and glued together, fastened to the wheel with counter-sunk coach screws, and turned up in its place. Strong steel or wrought-iron tubes make excellent spokes for the wheels, combining as they do strength with lightness. With the object of preventing the upper saw wheel overrunning the lower, some engineers make the latter about one-third heavier than the former, so that the increased momentum may prevent its speed being materially reduced when an increase of work is put upon it. For machines where the duty is very severe, the spokes of the wheels may be 'staggered' with advantage; in this case the centres should be made heavier, and the rim of the wheel strengthened with wrought-iron plates or pads where the spokes are attached. The top wheel can be set to an angle with the lower wheel by means of a set screw, cam, or worm gearing, whichever the arrangement of the wheel or slide may render most convenient. Wheels without flanges are to be preferred, as the flanges do little to support the back of the saw blade, and have a tendency to twist and buckle it, and heat and crystallise the steel. Some American makers construct the lower saw wheel of greater diameter than the top, but the writer fails to see the advantage of having the arc of contact of the saw different on the two wheels. By thus lightening the top wheel the tendency to overrun the bottom wheel would of course be reduced. With the same object in view—viz. to equalise the speed of both wheels—centrifugal governor gear has also been fitted to the top wheel, but the writer is unable to speak from experience as to its success or otherwise.

TENSION APPARATUS.—To secure effective working, and prevent as far as possible the fracture of the saw blade arising from a rigid tension, the slide or bracket carrying the top wheel is always mounted elastically. This is effected through the medium of a strong spiral or coach spring, or by means of a counterbalanced compound lever, the amount of tension in the latter case being regulated by moving the weight nearer to or farther from the fulcrum. No absolute rules can be made as to the amount of tension necessary on the blade, as this depends largely on the size and nature of the wood, the gauge, width, and condition of saw, and rate of feed of the wood. If the rate of feed is fast, the tension of the saw must be increased to enable it to face the wood without buckling. Great tension is bad, and often leads to fractures, especially if there should be any small cracks in the blade, a condition often found in saws of hard or crystalline steel. More tension on the saw should not be given than is required to keep it to the line. The slide should be so evenly elastic that, should the saw meet an obstruction and give a jump, the spring or lever compensating arrangement would give with it, and so save a fracture.

SAW GUIDES.—One of the chief troubles found in the early band-sawing machine for logs was the difficulty of keeping the saw blade in a true vertical line when sawing heavy timber. . This has now, however, been in a large degree surmounted by means which we will briefly discuss. In the first place it is important that the saw be guided and supported as it enters and leaves the wood. This has been done in a variety of ways. The best with which we are acquainted is to fit in the table an adjustable metallic friction revolving guide wheel to receive the back thrust of the saw, and an adjustable guide fitted immediately beneath the table, with a similar guide arranged in an adjustable counterbalanced slide, fixed immediately above the surface of the wood. If the work is very difficult two pairs of movable steel rollers placed immediately above the cut and below the table can be used. With these revolving rollers the friction is very small, and the saw is supported considerably. The ordinary flat adjustable guides are usually of wood. Apple or pear wood soaked in oil is suitable, but some makers use plates of steel. In sawing resinous woods, where it is necessary to keep the blade clean by lubricating it, the writer has used with advantage an oil-box guide. This is made in gun-metal, and consists chiefly of two flat oil-boxes, placed one on each side of the saw. The sides of the boxes nearest the saw blade are made adjustable, and drilled with a number of small holes, through which the oil can percolate. Hard brushes can also be fixed to sweep the blade clean at the back of the machine with advantage. The packing pieces, whether of wood or metal, should be adjusted so as to just touch the blade on either side, and so prevent its undue vibration in working. Another plan to keep the saw to the line is to deflect the blade as it enters and leaves the cut by means of side friction rollers placed on a spindle vertically and made to bear against it. The revolving steel roller receiving the back thrust of the blade must be capable of adjustment, as the duty is very severe, and the blade must not be allowed to cut too deeply into it, or it will have a tendency to heat and twist the blade. The roller need not be more than ½ in. thick; it should be about 4 in. diameter, made of hardened steel, fitted on a steel spindle carefully mounted in phosphor-bronze bearings. These, together with the lower side guides, can be mounted with advantage on a bracket arranged to swivel so that the guide may be readily adjusted to the plane of the saw blade.

We illustrate in fig. 44 an improved form of guide and guide arm, of American origin, in which the pivot is in line with the teeth of the saw, but slightly to one side, and it is stated that the amount of movement which this position entails upon the cutting edge of the saw is so slight as to be immaterial. The hardened steel roller is fitted between steel plates; the outside plate is ⅜ in. thick, with a slot cut in it to make room for the nut on the roller. This outside plate is bolted to the guide casting by three stud bolts, which pass through adjusting steel plugs, thus enabling the distance between the plates to be altered at will. The upper and lower edges of the plates are bevelled as shown, and the side guides, which are gibs of brass or steel, are slipped on and screwed fast. The whole guide is then pivoted close to the cutting edge of the saw, and by loosening one nut the guide may be adjusted by the handle shown at the back whilst the saw is in motion.

We have seen another very good guide, consisting of a hard steel disc arranged to rotate on its axis, so as to present fresh wearing surfaces to the back of the saw. The side guides are two half discs, which are made to embrace the sides of the saw, and can be readily adjusted by a screw when the saw is in motion.

TIMBER CARRIAGE.—This is usually a table of wrought iron running on friction rollers or rails, and operated by steam, rack and pinion, or friction gearing.

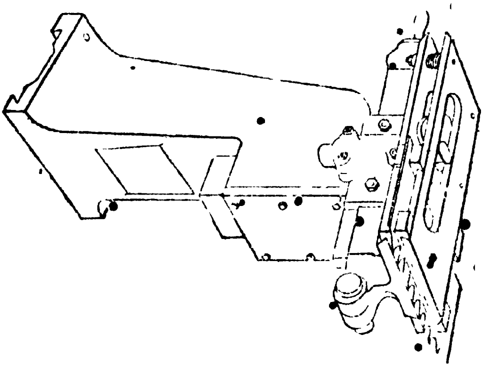


FIG. 41.—GUIDE AND ARM.

It should be fitted with adjustable sliding heads and dogs for holding the timber firmly in position, and be speeded to travel from, say, 5 ft. to 100 ft. per minute, according to the size and nature of the wood to be sawn. By means of a hand-lever and suitable friction gear the traverse of the table may be readily started, stopped, or reversed, as may be required. By the employment of a friction disc the rate of feed may be regulated to a nicety. Rope feeds and feeds similar to those used in rack saw benches are also used, but care must be taken that the speed of the feed is not excessive, or the saw blade may be buckled and broken, as, being of much thinner gauge and usually running at a slower speed than a circular saw, it will not stand so much 'crowding.' The levers and hand wheels controlling the stopping, starting, feeding, and adjusting of the logs should be placed so as to be readily under the control of the operator, and as near together as may be. In the most advanced machines the head blocks can be simultaneously moved by a lever, and the thickness of the cut regulated to the greatest exactness by means of an indexed gauge plate.

Band Saw Blades.—It need hardly be said that no matter how well a machine be designed and made, unless the cutting tool is of the finest quality the result is always unsatisfactory. What is required in a band saw is toughness combined with a certain degree of hardness. If the blade be too soft it will not stand to its work, and will require constant sharpening. If it be too hard it will crystallise and break; it must, however, be sufficiently hard to keep well its cutting edge. French bandsaws have long been held in the best repute, but some English firms are now making very good ones. It is not easy to distinguish by inspection the quality or temper of a saw blade, and a user must necessarily rely to a great extent on the repute of the saw maker. Not a bad test is to 'hammer set' a few of the teeth coarsely, and if the temper is too hard a tooth will probably crack. The gauge of the saw should be in proportion to the diameter of the saw wheels and the nature of the work. A thin gauge saw will stand better than a thick one, therefore a saw of a greater gauge than is required to stand up to the work should not be selected; but for cutting hard, close-grained woods, such as oak, beech, &c., a thicker saw will be required than for medium and soft woods. Long blades will stand better than short ones. To do thoroughly satisfactory work a band saw should have teeth correct in shape, and the blade be uniform in gauge, width, toothing, sharpening, setting, and temper. The question as to the shape of the teeth is a matter not easily dealt with, as it should be regulated by the nature of the wood they have to cut. Teeth with square or angular gullets should be avoided, as they are more likely to crack at the roots of the teeth than those with rounded gullets. For converting ordinary timber a saw with teeth similar to fig. 45 is suitable. For sawing oak, ash, elm, and hard woods generally[1] more teeth should be used than for soft wood, and these filed farther back. For woods of woolly fibre, such as poplar, saws with deep teeth and coarse space and set should be employed, to allow an easy clearance for the sawdust, and overcome its clinging properties. Coarse teeth and set should also be used for cutting pitch pine. For soft woods ordinary hand-saw teeth are often used. It is important that all the saw teeth be sharpened and set alike. With this object in view, automatic sharpening and setting machines have been introduced with satisfactory

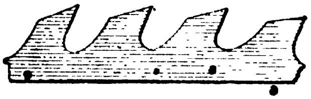


FIG. 45.—SAW TEETH FOR ORDINARY TIMBER.

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[1] See *Saw Mills, their Arrangement and Management*, by M. Powis Bale.

results. A suitable gauge for saws 8 in. wide for cutting soft and medium woods is 17 S.W.G. with a pitch of about $1\frac{1}{4}$ in. The amount of set should vary according to the density of the wood, the harder the wood the less the amount of set necessary and the greater the number of teeth. For converting very hard woods, such as iron wood, the author prefers fine-toothed and set mill saws to either circular or band saws. For sawing deals, band-sawing machines carrying two blades have been introduced into this country with success, a cutting speed of about 6 ft. per minute being maintained, with a kerf loss of about $\frac{1}{16}$ in. for each cut. It is very important, in order to secure an even motion on the saw blade, that the brazing be very completely done, and that the joint be of exactly the same thickness as the rest of the blade.

Speed of Saw Blade.—The question of the speed of the blade is a factor of considerable importance in securing efficient working. A short saw running over medium-sized wheels cannot, with safety, be run so fast as a long saw running over large ones, by several thousand feet per minute. A speed of from 5,000 ft. to 10,000 ft. per minute—according to the nature of the work and construction of the machine—may be considered a fair margin.

Notes on Working.—Keep the saw to a moderate tension and see that the wheel coverings are not allowed to get rough or worn. When sawing resinous woods, keep the blade as clean as possible by lubricating and brushing it. After taking a cut the log should be set back very slightly, so as to clear the teeth of the saw, as the table runs back, preparatory to taking another cut. The saw should never be crowded with too quick a feed, or it will twist and buckle and not cut true and regular. Emerson, an American manufacturer of saws, gives the following instructions for straightening band saws. If band saws contain lumps or twists, put them on the wheels, and at the tension they are to be run. Use a light, oval-faced hand-hammer for thin, narrow saws, a heavier hammer for wider and thicker ones, and a short straight-edge, say 6 in. long, for narrow saws, and a longer one for wide saws. The tongue of a carpenter's or machinist's try square, if straight, will answer. Go over the saw carefully with the straight-edge, and mark the lumps and high places on both sides of the saw. Now hold the oval face (end) of a carpenter's or millwright's mallet against the side of the saw, exactly on the opposite side from the marked places, which should be marked with chalk. You will find that a few light blows against the saw opposite the smooth face of the mallet will knock out the lumps. Work on both marked sides as you go along, watching very carefully with your straight-edge as you proceed, and you will at once see that the lumps or high places begin to disappear. If your saw has been sprung edgewise by gumming or cutting out the teeth with a press gummer, take most of the weight off the saw, so as only to have barely tension enough to hold the saw straight on its sides; use a long straight-edge, say 18 in. to 20 in. long, and be sure that it is straight. If the back of the saw is found to be hollowing, hold the face of a heavy hand-hammer against one side of the saw, and, with a lighter hand-hammer, hammer the blade against the face of the large hand-hammer, commencing at the edge of the saw near the back, working towards the roots of the teeth, thus stretching the saw at the back. Striking light blows on a thin, narrow saw, and heavier ones on a wide, thick saw, will soon bring them straight on the back. The principle of this operation is that you stretch the steel at the back of the saw. A band saw will work badly if the cutting-edge becomes stretched so that it is hollow-backed. It will work much better if the back is stretched a little longer than the cutting edge, so that it will be a trifle rounding on the back (but not too much). Then, when the saw is strained up, the cutting-edge will be a little tighter than the back. With a little practice, care, and perseverance, any ordinary mechanic can make a good job, with tools that he can pick up in almost any shop or mill using band saws, and will be surprised to learn how quickly he can go over a saw, and how much he can improve the working of it. Unless you want to stretch the saw, use wood and not iron or steel to hammer against.

CIRCULAR AND BAND SAWS COMPARED.—Circular saws for breaking down heavy timber, when compared with band saws used for the same purpose, possess the advantage of greater output, and are perhaps a little more easily managed. On the other hand, the band saw uses much less power and wastes much less wood. The first cost of a good rack-feed saw bench and a band saw for logs is slightly in favour of the former. In America, where circular saws are used of much thicker gauge than they are here, the saving in power and wood through using a band saw is correspondingly greater. In sawing pine the average output on a first-rate circular saw in America may be set down at about 40,000 ft. per day of ten hours, whilst a band saw in

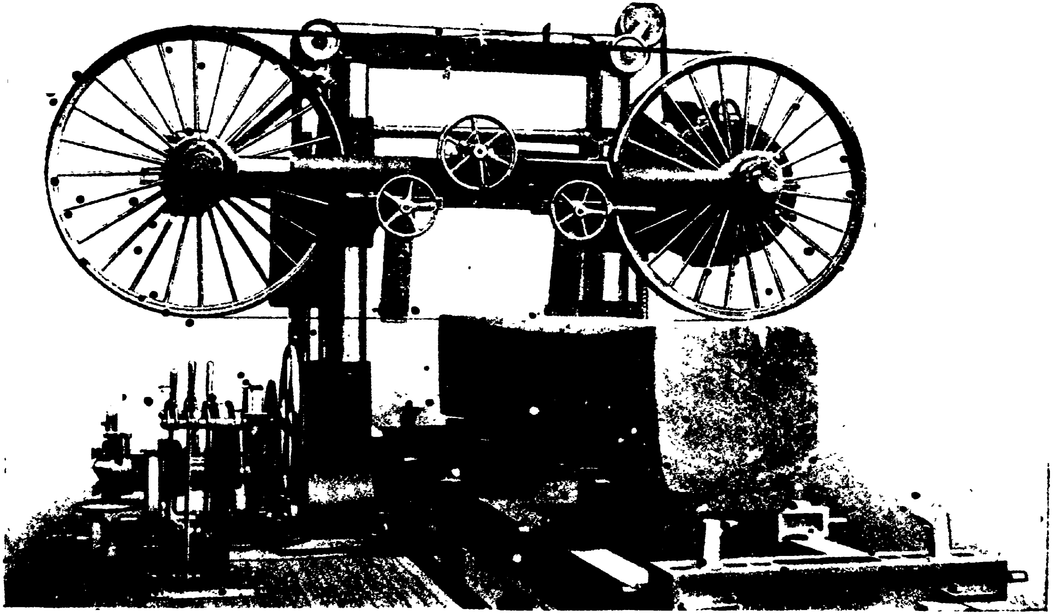

FIG. 46.—HORIZONTAL LOG BAND SAWING MACHINE.

the same time would produce about 30,000 ft. We believe these figures have been exceeded, but think they may be taken as a fair average. An American authority, in comparing circular and band saws, says that 'the kerf of circular saws average $\frac{5}{16}$ in., and in sawing 1,000 ft. of inch boards 312 ft. is turned into sawdust. The average kerf of the band saw is about $\frac{1}{12}$ in., and in sawing the same amount of boards it turns 83 ft. into sawdust. This shows a clear saving of 229 ft. in favour of the band saw on every 1,000 ft., and on 1,000,000 ft. of 229,000 ft.,' an enormous saving to say the least. The figures here given must, however, be very considerably discounted when applied to this country, as the circular saws in use here are of very much thinner gauge; but supposing a reduction of 50 per cent., and the saving is still very great. This is, of course, particularly the case when valuable woods are converted. Again, if the band-sawing machine is carefully made and handled, the work produced is superior to that of the circular saw. This may be chiefly accounted for through the greater freedom from vibration of the band saw when cutting. As the advantages arising from the employment of band saws become better known and appreciated, there is little doubt that they will, on their merits, rapidly supersede large circular saws for converting heavy logs.

Fig. 46 represents a patent horizontal log band saw by A. Ransome and Co., Limited, who have long made a special study of this type of machine.

As will be seen from the illustration the entire machine, including the gear for working the travelling carriage, and for raising and lowering the saw carriage, is mounted on a cast-iron bedplate, and this being fixed on a bed of concrete on the ground level, no excavations are necessary.

The saw wheels are made of tough cast iron, and fitted with wrought steel spokes cast in, the driving wheel being somewhat heavier than the driven one to prevent over-running. Both wheels are turned all over and accurately balanced, and the spokes are set staggered. The saw blade is run metal to metal at a speed of 7,500 ft. per minute.

The saw-wheel spindles are of steel running in long antifriction roller bearings.

The requisite tension to the saw blade is regulated by a patented arrangement of levers, which can be readily varied to suit different widths and gauges of saws, and it is claimed that the tension always remains constant, any elongation of the blade being automatically taken up by a weighted lever.

The casting on which the saw wheels are carried is provided with two long sockets, which are bored to fit the two vertical columns of the machine on which the saw carriage rises and falls, and as these sockets are long and of large diameter, the wear on them is very small and they will work for a long period without vibration, an advantage over the ordinary flat slides and strips which require more or less frequent adjustment.

The vertical movement of the saw carriage is actuated by two strong, square-threaded screws which are made to rotate in either direction by suitable machine-cut gearing. An adjustable rotary micrometer and pointer is fitted, by which the operator can adjust the saw with great exactitude to cut boards of any desired thickness without measuring or calculation, and the distance of the saw from the log carriage is shown by a rotary scale which automatically indicates the exact position of the saw.

CHAPTER XLII.

THE CONSTRUCTION AND MANAGEMENT OF BAND-SAWING MACHINES.

Many of our remarks on log band-sawing machines will apply also to those of ordinary construction, but we may say that, to make a really efficient machine, the main framing should be rigid and cast in one piece, and of a height not greater than is absolutely required for working. Hollow or 'box' framing is to be preferred, but for light machines a stout flange casting may be sufficient; the base of the machine should be extended, and, given these, freedom from excessive vibration in working may be secured.

To insure easy manipulation of the wood, it will be necessary to bow the main frame sufficiently to allow of ample space between it and the saw. The next most important point is the construction of the saw wheels. These should be of as large a diameter as may be convenient, and combine strength with lightness in the highest possible degree, and be perfectly in balance. An elastic rubber band or cushion must also be provided for the saw to ride on.

In the best practice the old cast-iron flanged wheels have given place to light steel or wrought-iron ones, made somewhat after the fashion of bicycle wheels and without flanges. The top wheel is arranged to cant, thus directing the saw to run on any part of the periphery and equalising the wear on the elastic covering. The top saw wheel must be mounted elastically, and the author has found for heavy machines two pairs of bearings—mounted in a slide for the top wheel, and in standards or pedestals for the bottom wheel—to be preferable to single bearings or the plan of mounting the wheels to run on studs. To keep the saw to its proper tension, and lessen the breakage of the blades, a weighted counterbalance lever, or a spring arrangement, must in all cases be fitted to the top slide. An extremely important matter is the guiding and supporting of the saw blade as it enters and leaves the wood; this may be done by fitting in the table metallic friction guide wheels to receive the back thrust of the saw, an adjustable wooden guide immediately beneath the table and a similar guide fitted in an adjustable counterbalanced slide fixed immediately above the surface of the wood.

The table must, of course, be arranged to set to angle: this is usually done by means of a slotted quadrant and stud, but the trouble of unslacking the nut and uncertainty of fixing the table may be obviated by forming a worm on the quadrant, and working it by a worm and hand wheel. The table can thus be set to any desired angle with the greatest nicety.

Before commencing work, the machine should be carefully fixed to a dead level, and it would be well to place beneath the base-plate a sheet of felt, as this has a tendency to absorb and lessen the vibration in working, especially if the machine be placed on an upper floor.

THE BREAKAGE OF BAND-SAWS.

Why do band saws break? that is the question.

Many people would probably say because they are not strong enough; but when we consider that the limit of endurance of a jointed and strained band saw blade is not less than 180 lbs. for every $\frac{1}{16}$ of its width, something beyond fair usage must account for their constant breakage. I take it the chief causes of breakage may be set down as follows:—

1. Improperly or badly constructed machines.
2. Bad saws.
3. Saws of too thick a gauge for the diameter of the wheels.
4. Saw wheels too small, too heavy, or out of balance.
5. Want of elastic tension in mounting the saw wheels.
6. Too great or sudden a tension, or wheel covering worn, or out of order.
7. In overcoming the inertia of starting the top wheel, and from the top wheel overrunning the bottom wheel and saw.
8. From the expansion of working and the omission to loosen the saw blade as it contracts after finishing work.
9. Improper method of receiving the back thrust of the saw.
10. From imperfect brazing and the joint being thicker than the other part of the blade.
11. From chips dropping between the blade and the bottom saw wheel.
12. Insufficient guides for the saw as it enters or leaves the cut.

13. Improper teeth or width of blade for the wood or work to be done.

14. Improper and uneven sharpening and setting.

15. Improper speed.

16. Improper working, such as forcing the saw, using dull saws, &c.

There may be other reasons for breakage than above, but these are the chief ones the writer can call to mind at the moment; practical readers can add to the list.

Referring to cause of breakage No. 1 on the list, we have already given some notes on the points to be desired in a well-constructed machine which will sufficiently answer this.

With reference to band saws (No. 2), the user has to a great extent to place himself in the hands of the saw-maker, as it is difficult to distinguish by inspection the quality or temper of a saw blade. By bending the blade or by setting some of the teeth coarsely you can in a degree judge its elasticity as to its temper, as, should it be too hard, it would probably crack. A blade either too hard or too soft is useless; what is required in a band saw is toughness, and a certain degree of hardness combined. (3) A fruitful cause of breakage of the blades is the use of band saws of too thick a gauge for the size of the saw wheels on which they run. The blades when in work are subjected to several severe strains, the chief of which are bending and torsional; this is particularly the case when thick saws are run on wheels of small diameter, as the arc of contact of the saw and wheel is too sharp. It is a mistake to use thick saws; *a thin gauge saw will stand better than a thick one.*

4. As we have elsewhere remarked, saw wheels of small diameter are to be avoided. We prefer to run wheels without flanges on them. 5. A very important point in working band saws is to secure a constant and even tension on the saw blade; at the same time the tension should be elastic, and not rigid, to allow for the expansion and contraction of the saw, as the friction of working sets up heat which causes the blade to expand, and when the machine is at rest, and the blade becomes cool, it contracts again. Should the saw catch in a knot or nail and give a jump, if the top saw wheel is mounted rigidly it will almost invariably snap, but should it be elastically mounted it will give with the saw, and so save its fracture.

6. Some operators run their saws at too great a tension, and should this be suddenly increased by the saw striking some hard substance, fracture is the result; or if the elastic saw wheel covering is allowed to get worn the saw becomes twisted in running and breakage often ensues. This latter can be avoided by arranging the top saw wheel to cant, and so leading the saw to any part of the periphery, and thus equalising the wear of the rubber covering. Should saws be run at too great tension, the excessive friction rapidly alters the granular structure of the steel, which becomes crystallised and soon cracks and fractures.

7. In working band-sawing machines it is important that they should be set in motion gradually, more particularly where the wheels are of the old-fashioned type and heavy, as it takes a little time to overcome the inertia of the top saw wheel, and if the power is applied all at once there is a considerable tendency to snap the blade from the sudden strain put

upon it. To overcome this, striking or belt gear can be worked by means of a very coarse screw. This can also be applied to the starting of heavy planing machines with decided advantage.

A fruitful cause of breakage of the blades is the overrunning by the top wheel of the bottom or driving wheel of the saw, and also of the saw itself. When the top saw wheel is running at full speed it necessarily acquires a considerable momentum, and acts somewhat after the fashion of a fly wheel; consequently, when the speed of the saw blade is suddenly checked by its entry into the wood as it commences to saw, the acquired momentum of the top wheel not being checked in a like proportion overruns the saw and the driving wheel, and creeps, so to speak, up the back of the saw, and consequently buckles or breaks it at the point of resistance, viz. where the saw enters the wood. The remedy for this is to construct the top saw wheel as light as possible, make it in perfect balance, mount it elastically, and cover it with a thick band—say ¾ in.—of vulcanised indiarubber. These arrangements will neutralise to a considerable degree the sudden strain put on the saw at starting, and largely obviate the overrunning above alluded to.

8. *Saw blades should in all cases be slackened out after finishing work.* Notwithstanding the small area of the blade in frictional contact with the wood, and the constant cooling action of the air through which the saw passes, a considerable amount of heat is often engendered in the blade, especially in sawing resinous or difficult woods. Consequently, the blade expands considerably, and the slack is taken up by the operator. When the work is over, and the friction on the

blade removed, it immediately commences to contract. Should it not be at liberty to do this, from the tension not being removed, cracks at the roots of the teeth are the result; consequently, when the saw is started again it flies. When rubbers are put on the wheels new they may give sufficiently to allow of the necessary contraction, but when they become worn and hard or where leather coverings are used, the above is usually the result.

9. Another cause of the breakage of the blades is an improper method of receiving their back thrust. The best way to do this has been the subject of considerable discussion. We prefer to fit revolving steel discs for this purpose, as the back of the saw blade does not so readily cut into them as with fixed ones. If a disc is allowed to get deeply grooved, the blade gets buckled and twisted, and often breaks.

10. Imperfect brazing is another cause of breakage. To secure a steady and even motion on the saw blade, it is important that the brazing be carefully and neatly done (see p. 338).

11. Chips may be prevented dropping between the saw blade and the bottom wheel by attaching an angular guard to the frame of the machine.

12. No comment is needed with respect to insufficient guides.

13. The proper shape and pitch of the teeth is a matter of great moment in the successful working of band saws. Should teeth be used unsuited to the wood being cut, a largely increased friction on the blade is set up, the teeth are rapidly dulled or broken, and the work turned out is inferior. For sawing all ordinary woods of the *Pinus* family ordinary hand saw teeth are

suitable, except for pitch pine; for working this wood coarsely spaced and set teeth are suitable. We can recommend for durability saws with gullet teeth, that is, rounded at the root, as they are less liable to fracture than saws with the roots running to an angle, as the fracture in the blade is found almost invariably to commence at the point of this angle. Owing, however, to small gullet teeth being more troublesome to sharpen, the hand saw teeth are now largely employed. For sawing oak, ash, elm, and hard woods generally, more teeth or points, say five or six to the inch, should be used, and these filed farther back. For heavy sawing, peg teeth with round gullets are to be preferred. For woods of woolly fibre, such as English poplar, saws with deep teeth should be used, with coarse space, and set to allow an easy clearance for the sawdust and overcome its clinging properties. Saws of a width suited to the work should be used, and wide saws should never be twisted round sharp curves, or they will buckle and run out of truth. For straight work a wider saw may be used with advantage.

14. Care must be taken that the saw teeth are uniformly set and sharpened. Uneven and improper setting causes a considerable amount of tension to the saw blade, increased friction crystallising the steel, and consequent breakage. The teeth of band saws should by preference be set by light, carefully given blows, instead of bending, which unless very carefully performed, is more liable to buckle the blades and prevent them running true. Several little machines are now made, by which saws can be accurately set to any desired coarseness by a blow similar to that given by a hammer instead of by a bending pressure. A band saw sharpening machine has also been constructed, which

automatically sharpens all the teeth alike. By improving the quality of the work and reducing the friction on, and consequent breakage of, the saw blades, these machines should very rapidly earn their first cost.

15. The speed at which the saw blade travels has much to do with its cutting efficiency. Saws running on small wheels, say, below 3 ft. diameter, cannot be run with safety so fast as on larger wheels. Speaking generally, saw blades working on wheels up to 3 ft. diameter can be run up to 4,500 ft. per minute for soft and medium woods, that is, presupposing a well-constructed machine to be used. For sawing hard woods up to 3,500 ft. per minute, with saw wheels above 3 ft. diameter, these speeds may be increased.

16. We need hardly say a bad workman may break any amount of saws by forcing them, bending them edgeways, using dull saws, or saws too wide or stout for the work, &c. If in working a properly sharpened and set blade should have a tendency to bind, it probably arises from insufficiency of throat room in the teeth. It would be well, therefore, to try a saw with the teeth set a little further apart: this will not cut quite so fast, but the sawdust will have time to escape, and the binding should be done away with.

In concluding our remarks on working band saws, there is little doubt that—given in the first instance a well-constructed machine, a careful operator, and a saw blade uniform in gauge, width, toothing, sharpening, setting, and temper—a band sawing machine is one of the most money-earning and valuable of all wood-working machines, not only for the ordinary curved work, for which it is generally used, but for breaking down heavy logs.

CHAPTER XLIII.

CIRCULAR SAWS: THEIR ADJUSTMENT AND MANAGEMENT.

As good saws cannot run properly in a bad machine; it may be as well to consider briefly, in the first place, what points of construction are to be desired in a really efficient saw bench. In the most advanced practice the main frame is invariably made on the 'box' system, and cast in one piece, and there is little doubt that the strains and vibrations of working are thus more readily absorbed than is the case where the frame is put together in sections. The face and edges of the table must be truly planed.

We now come to a very important matter in all wood-working machines, viz. the bearings; and we cannot help thinking that, having in mind the constant and severe strains to which they are subjected, the majority of them in this country are made much too short; the bearing surface is thus limited, and consequently the pressure on it is very great. In America long bearings have been the rule for years, and some few English firms are at length introducing the system, with the result that, owing to the pressure being distributed, the friction and consequent heating and wear are reduced and their longevity largely increased.

In preference to white metal alloys as used in the

States, gun-metal and phosphor-bronze are the materials usually employed here, and a bearing of from three to four diameters in length can be recommended. For all saws above 30 in. in diameter, three sets of bearings should be fitted, one of these being placed outside the driving pulleys to overcome the pull of the belt. The author recommended that this latter bearing be made adjustable for wear; this can readily be done by dividing the bearing vertically and unevenly, and by passing set screws through the side of the pedestal. In large benches, at any rate, it will be found convenient to let the bearings in from the top of the bench and fit in false plates in preference to fitting them in plummer blocks bolted to the under surface of the frame. To insure the saw spindle running true, all bearings should be bored out in their places instead of in a lathe as is occasionally done. The saw spindle should be of steel and free from seams or hard places, and fitted with an adjustable lock-nut to take up the end wear. The saw collars and steady pin should be very carefully made, and the latter be an easy fit, or it may throw the saw slightly out of centre. The hole in which the pin is fitted should be countersunk. The fence should be very accurately planed, arranged to bevel, and fitted with strips and fine adjustment screw for accurately gauging the thickness of the cut. In heavy machines, a lever pressure roller and weight for holding the wood up to the fence will be necessary; and the drag-rope, roller, chain, rack or other feed for taking the wood through the saw is usually fitted. We take it a very important factor in the effective working of circular saw benches is found in the diameter and width of the driving pulleys employed. Many of these are undoubtedly made of too small a diameter and too narrow on the face for the work they have to perform; on this point we shall have something to say further on. These pulleys should be crowned on the face, and the pulley driving them flat, and of a width equal to both of them. With reference to the loose pulleys on saw benches, there is little doubt that they are amongst the most troublesome things in a saw-mill to keep in order, and it may not be out of place to say a few words thereon. In the first place, they are not always properly designed for the work they have to perform, the same pattern being used for all kinds of duty.

For use on saw benches, where the speeds are high and the belts often heavy, the pulleys should in all cases be bored and rhymered perfectly true. If an ordinary loose pulley be used, the boss should be extended so as to project, say, an inch beyond the rim of the pulley; the inside of the boss should be recessed and an oilway cut. The pulley should fit the shaft easily but not loosely, so as to admit of a thin film of oil penetrating between the pulley and the shaft, the object being for the pulley to ride on the oil and not on the shaft. For use in saw benches, the loose pulley can, with advantage, be made of less diameter than the fast, so that the driving belt is relieved from strain when not at work and has time to recover its elasticity; it is usual in this case to make the loose pulley with an inclined flange leading up to the fast pulley to facilitate the shifting of the belt.[1] The oil-holes should in all cases be of ample size, and either a lubricator or pipe fitted. The lubrication should be carefully attended to, especially when the pulley is new; should it once be allowed to seize, it will require re-rhymering, or it will be constantly giving trouble. If properly fitted and lubricated, cast iron makes an excellent wearing surface; a little fine plumbago introduced into the oil will keep it longer in the bearing, and by filling up the little pores in the iron, produce a fine, smooth surface. Should the loose pulley be made of less diameter than the tight, the difference should not be great, say not more than 1 in., or, in shifting the belt from the loose on to the tight, it will become unevenly stretched on the one side, and be apt to run out of truth. In many cases it will be found an excellent plan to arrange the loose pulley to run on a sleeve of cast iron. A patent in this direction has been taken out, of which we hear satisfactory results. In this plan the boss of the loose pulley is somewhat enlarged, and made to revolve on a sleeve instead of on the shaft itself. The pulley boss is recessed to form an oil chamber, and the oil is supplied in the usual way through a pipe, and is prevented from leaving the bearing by means of a flange fitted to the end of the boss, and by the centrifugal force engendered when the pulley is set in motion, which causes the oil to fly immediately to the largest diameter, which is the working or rubbing face of the sleeve. Tight belts, often too narrow for the work, are a fruitful cause of loose pulleys grinding on the shaft and getting out of order. The author has recently patented a system of bushing loose pulleys with glass, which has every appearance of being highly successful. In this case the bush is crenated in such a manner that a supply of lubricating material—of which very little is required—is retained in it.

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[1] *Saw-mills: Their Arrangement and Management.* By M. Powis Bale

Circular saws may run out of truth from a great variety of causes, amongst which the following are perhaps the chief, but practical operators will be able to add to the list:—

1. Saws of too thin a gauge for the work.

2. Irregular setting.

3. Improper form of teeth for the work.

4. Too rapid a feed of the timber.

5. Improper sharpening of the teeth

6. Teeth of an improper pitch, or with insufficient gulley space to allow sawdust to escape freely.

7. Saw plate unevenly 'balanced,' or improperly hung.

8. Saw becoming 'buckled' through overheating from the friction of the wood or heat from bearings &c.

9. Collar or steady pin of saw spindle out of truth.

10. Saw plate of too mild a temper or untruly ground.

11. Saw not compensated, hammered, or distorted enough when cold—by the maker—to run true when warm and at its full speed.

12. Too much 'lead' or rake on the saw teeth.

13. Saw teeth allowed to get out of space or shape.

14. Too long a saw guide or fence, causing binding of the wood.

15. Improper packing of the saw.

16. Binding of the timber through 'not being opened out' as it leaves the saw, or other causes.

17. Chips getting between saw and packing pieces.

18. Through end play on the spindle.

19. Driving pulley on the saw spindle being of too small diameter, or too narrow on face, causing slipping

of belt and consequent marking on the wood, or running driving belts at too short centres.

20. Using a 'frozen' saw.

21. Saws running at too high or too low a speed.

1. The thinness of the gauge at which a saw may be safely run depends in a large measure on the nature of the wood being cut and the skill of the operator in selecting the right shaped tooth, sharpening and 'packing' the saw properly, and keeping it in what may be termed scientific order. In America thick gauge 'distorted' saws, run with guide pegs, but without packing, have been the fashion, but, as this means loss of power and wood, they will, as wood becomes dearer, doubtless give way in favour of thinner ones. In selecting a saw, what is required is one of a gauge not so thick as to waste unnecessarily power or wood, or so thin as to give constant trouble to keep in order. It must also be borne in mind that the thinner the gauge of the saw, the more teeth will be required to allow of the same amount of feed; the power required will, however, be increased in ratio. A thick saw can be run at a higher speed than a thin one, as it expands less rapidly from the centrifugal force set up, and is less likely to become 'rim' or 'centre' bound.

2. Irregular setting is a frightful cause of saws running from the line and turning out bad work. Setting by rule of thumb is a stupid and wasteful plan; in all cases a gauge should be used, whether spring, hammer, or spread setting be employed. In working, it is found that the teeth of a saw wear at the side of the points, and if some teeth have more set than others, these are strained unduly, and rapidly worn away, and

from the severe and uneven friction are often heated, and are inclined to buckle and run from the line. The operator must exercise his judgment as to the amount of set required to suit different kinds or conditions of wood, as it is both useless and wasteful to give a saw more set than is absolutely necessary. Care must be taken that both sides of the saw are set alike; should one be set more than the other the teeth will, of course, lead or run from the line.

3. If teeth of an improper form or unsuited to the nature of the wood being cut are used, we need hardly say that a great amount of friction is set up; in some cases the teeth are broken, and the result is in every way unsatisfactory. Teeth of almost any shape and in any condition can be driven through the wood by sheer force, but this is mangling, not sawing. What is required are teeth of the correct shape for the nature of the wood sawn, and equal in pitch, space, bevel, gullet, length, and set. This list may appear a long one, but users will find that any reasonable amount of time spent in keeping saws in fine condition, and working them in a scientific manner, is a very paying investment, the result being more work of better quality, less wear and tear and expenditure of power. The question of the shape and cutting action of saw teeth is a scientific matter of much importance to timber converters, but it would require many drawings and much space to discuss the subject fully. We may say, speaking generally, that for cutting soft wood the angles of the teeth should be more or less acute, according to its softness, and those for medium and hard wood more obtuse in ratio to the varying densities of the wood. It may be some little guide to know that when a saw is

cutting 'sweetly' it should produce extremely minute chips like those from a mortise chisel, and not very fine sawdust; if the latter is made the saw is scraping, not cutting. Whatever teeth are selected, should they spring or tremble in work, it may safely be concluded that they are unsuited to the work in some way, possibly either too long or too hooked, or of too thin a gauge.

4. Too rapid a feed of the timber is a matter that can only be judged by the sawyer, and depends entirely on the nature and condition of the wood being cut, the kind of feed gear, and the condition of the saw. Of course no one would attempt to feed hard, frozen, or difficult wood much more than half as fast as soft, and some woods, such as cocus, rosewood, &c., at less than this. If the feed is too fast, the timber will often rise up the back of the saw, and in some cases the sawyer will get a gentle reminder by having it thrown at him, or the saw will become jammed and buckled, or the driving belt thrown off. "Swaged" or spread set teeth will stand a quicker feed than spring set.

5. An immense variety of opinions exist as to what is the proper way to sharpen a saw, almost every operator having ideas of his own, good, bad, and indifferent, chiefly the last two; consequently we find an immense quantity of badly and improperly sharpened saws. We ourselves thoroughly believe in sharpening with a machine with which there is no difficulty in getting each tooth of the saw alike in its cutting angle, pitch and depth of gullet. The great point to aim at, whether emery wheels or files are used, is to sharpen each tooth so that it will take its allotted share of work; to effect this, the cutting angles of the teeth

must, together with the set, be exactly uniform. It is impossible, however, to properly describe the operation of sharpening in writing without an elaborate system of drawings. To keep all the teeth uniform we can strongly recommend the use of sheet steel standard templates of several teeth; by mounting these in a light, adjustable, radial arm, fixed on the sharpening stud, and made to bear flat against the saw plate at the periphery, the exact shape and depth of the teeth can be obtained from the template by traversing the saw round by hand.

6. A fruitful cause of saws buckling and running from the line is the insufficiency of throat space in the teeth; consequently the sawdust cannot escape fast enough, and becomes clogged. The teeth should also be all of equal length; if not the longest teeth get the most work, and the cutting power of the saw much lessened. The length of the teeth should be regulated by the nature of the wood being sawn; for instance, for sawing sappy or fibrous woods, long, sharp teeth are necessary, but these must not be too long or they spring and perhaps break in work. The author is of opinion that many of the saws in use in Europe carry too many teeth, and he is in favour of the American system of using fewer teeth—if not carried to excess—as more throat space is given to the clearance of the sawdust, and less power is required to drive. The throat space of saw teeth should be varied according to the depth of the wood being cut, as it will be seen at a glance that teeth with a sufficient throat space to allow sawdust to escape freely in sawing 18 in. deep would probably become jammed in sawing double that depth.

For gulleting an emery wheel is much to be preferred to a fly press; the latter is wasteful and apt to spring the plate when punching out deep gullets. If a saw is kept in good order, and the teeth are not allowed to get short and stumpy, very little gulleting should be required at one time; in fact, the gulleting press should be conspicuous by its absence, and only be used for retoothing broken saws.

7. In hanging a saw care should be taken that it does not fit too tightly on the saw spindle or bind the steady pin. A saw, when properly hung, should, in the horizontal line, incline very slightly towards the timber, so that the teeth at the back of the saw may rise without scoring the wood. The saw should be perfectly in balance, that is, *perfectly round*; if it has teeth of unequal length, size, or shape, it is not properly or scientifically balanced.

8. A very common cause for saws running untrue is the heat conveyed from the bearings through the saw spindle to the eye of the saw, and many plans to get rid of this have been tried. It arises, of course, in the first place from the bearings being out of order, screwed up too tight, or from driving with too narrow a belt, which has to be strained too tightly, or from running at too short centres, which also necessitates a tight belt; thus undue strain and friction are put on the bearings and heat engendered. These defects can usually be remedied without much trouble. Many schemes for keeping the saw spindle cool have been tried, including one in which it is made hollow, and a stream of water allowed to pass through it and escape at the collar on both sides of the saw, the centrifugal force distributing it over the surface of the plate. To this spindle is fitted a contrivance for relieving the saw

and allowing a little end play when necessary, and when the saw is through the cut the end play is taken up automatically by means of a weighted lever and knuckle-joint arrangement. For sawing pitch pine and gummy woods which clog the saw plate, this plan of lubricating with water should be decidedly useful, as it keeps the saw clean and cool, and it may consequently be run with less set. With the same object in view the author has recently constructed a new form of ventilating bearing, through which a steady current of air passes; this has been tried, with very satisfactory results. A saw spindle has also been patented, in which the collars are arranged with a circular groove, and several rows of curved grooves extending to the periphery; when the spindle is in motion a current of air enters into the circular grooves and escapes at the holes at the sides of each collar, thus acting somewhat after the fashion of a fan, and keeping the saw spindle cool. It is needless to say especial care should be given to the matter of lubrication. Get an oil with plenty of *grease* in it, and add one part of finely powdered plumbago to three parts of oil, and, with properly constructed bearings, little trouble should be experienced in keeping them from heating.

9. Bear in mind if the collar of a saw spindle is only slightly out of truth, this is multiplied considerably in a saw of large diameter. Again, a seamy saw spindle with a bit of metal torn up is enough to throw a saw out, or if packing is used between the collars, and it is rucked up or uneven, it will have the same result. Saws are often blamed for cutting untrue, when the fault lies with the collars or pins. The side of the saw nearest the wood should be constantly tried with a

straight-edge, and should it be found to bulge in the centre, it will probably arise from the saw collars being out of truth, or improperly concaved. The collars should be carefully tried with a straight-edge, and any inequalities or lumps removed. If the collar attached to the saw spindle—that is, the one nearest the wood—is perfectly flat, have it removed and slightly concaved, when the bulge in the saw plate will probably disappear. Inequalities in the saw collars may be temporarily remedied by introducing one or more paper or thin leather washers between them and the saw plate. If a saw should permanently buckle or bulge even slightly, from any cause, it should be at once hammered, as by use the trouble will be increased, and be more difficult to remedy. A skilful sawyer can tell by trying a saw with his fingers when running whether it is buckled or out of truth, even if it be only slight.

10. This rests with the saw-maker. All circular saws should be made of the finest quality of steel, combining, as far as possible, toughness with hardness, be uniform in temper and gauge, and be ground on a face plate. It is important also that the saw be scientifically hammered, so that the tension or strain is properly distributed. 'Cheap' (?) common saws—in fact, all kinds of woodcutting tools—are dear at any price. No professional workman will be troubled with them, and no opportunity should be lost of warning the amateur against purchasing inferior articles, which will only be a source of trouble and vexation to him as long as he continues to use them.

11. No. 11 also rests with the saw-maker to a considerable extent, but not entirely, as the speed at which

the saw is run should determine the amount of distortion necessary. Thus a saw may be hammered to run perfectly true at a slow rate of speed, say 6,000 ft. per minute, but if this is quickened up to the standard speed, say 9,000 ft. or 10,000 ft. per minute, it may become wavy and pliant, and run out of truth. It therefore follows that, if saws are to be run at any unusual speed, the saw-maker should be so informed, that they may be distorted or hammered to a suitable tension, and the tension uniformly distributed. If a saw is distorted too much, either at the teeth or centre, it will, when subject to improper usage and the friction of sawing, become 'rim-bound' or 'dished;' hence the importance of a perfectly adjusted saw to commence with, and the absurdity of expecting fine work from a cheap saw. It is, of course, apparent that the rim of a circular saw runs faster than the eye, and consequently heats and expands faster. To overcome this unequal expansion, and allow the saw to expand equally and run true when in work, additional heat is created in the centre by means of 'packing' in this country, whilst in America the same end is attained by distorting the saw to a greater extent when hammered by the maker.

12. In sharpening saw teeth with a hook to them, such as is found in the different forms of gullet and brier teeth, care must be taken that too much 'rake' is not given to the teeth, or they will be found to tremble in work, dig into and draw the wood, and run from the line; of course, some woods will stand more rake on the saw than others.

13. Allowing teeth to get out of space will, in some cases, make a saw run untrue; say, alternate spaces

set wider than the others; the teeth following those spaces have more work put upon them, and being set all one way—say, to the right—they naturally pull hardest into the wood in that direction, consequently the saw runs to the right. Hence the necessity of keeping all the teeth uniform in space. This can readily be done by using an adjustable sheet steel template, shaped to the teeth in sharpening.

14. The author is of opinion that a not by any means unusual cause of a saw jamming and buckling is the use of too long a saw guide or fence, so that the timber becomes crowded against it and has not room to open out. A fence for rip saw should not, as a rule, project above three or four inches beyond the roots of the saw teeth unless very thin stuff is being sawn. For sawing deals &c. some makers now fit friction rollers in the fences, arranged to project slightly beyond the face of the plate.

15. The proper 'packing' of a saw, unless of very thick gauge, is a matter of paramount importance in its effective working. The object of packing, in addition to supporting and lubricating the saw, is to allow it to expand equally from the friction or heat created by the packing rubbing against it. To insure this it is very necessary that the saw is packed evenly and equally. The plan generally pursued in this country is to screw pieces of wood to the finger-plate, and below the saw table on either side of the saw, the wood being rebated to allow the hemp, gasket, or other fibrous material, charged with grease, to be packed in tightly on either side. There are a right way and a wrong way of doing even this simple operation, and care should be taken that the packing is put in evenly, and bears uniformly

and without undue pressure on both sides of the front half of the saw. However, in preference to the above, we can strongly recommend the following simple plan: *Take either two pieces of hoop iron or strips of hard wood of the length of the saw from the teeth to the eye, and of a width that will reach not quite flush with the top of the table; then take some flax or rope yarn and lap it evenly round the strips from end to end till they are made thick enough to fill the packing space and bear evenly and not tightly against the whole front half of the saw plate up to the spindle.*

Instead of packing the back half of the saw, as some do, take two small discs of leather and attach them to the wooden packing pieces which are fitted to the frame of the bench, so that they bear on either side of the saw at the back and near the rim or roots of the teeth, and so steady and guide it. It is a mistake to use much oil in the packing, as this is wasteful and unnecessary. The above will, we think, be found a decided improvement over the plan generally pursued—of ramming down packing on either side of the saw, as this is, at the best, uncertain, as should the packing be tighter at one point than another, or should it be lumpy, the friction on the saw plate is uneven, and it will often cause it to run 'wavy' and out of truth.

16. In sawing woolly-fibred and difficult timber special means should be taken to open them out as they leave the saw. This is usually done by the sawyer with wedges driven into the kerf by hand: this is often neglected, thereby causing many a saw to jamb and buckle. To obviate this, the use of a revolving opening wedge can be recommended; this should be fixed immediately behind and in the same line as the saw.

The wedge should be made preferably of steel, circular in form, and say half an inch thick at its centre, tapered down to a blunt edge at its circumference, its diameter being regulated by the size of the saw. It can either be arranged to project through the face of the bench, or be mounted on centres at the end of a lever, and suspended behind the saw. The wedge as it enters the cut is revolved by the friction of the wood, and thus relieves the saw from a considerable amount of side friction. Instead of a revolving wedge a fixed steel spreading-knife or wedge can be employed; in any case something of the kind is certainly to be recommended, as it tends to relieve the saw considerably, and is always there when wanted.

18. End play on the saw spindle should be prevented; this can be done by means of an adjustable lock-nut.

19. The use of driving pulleys too small in diameter and too narrow on the face is a fruitful cause of saws buckling, on account of the heat set up in the bearings through the use of narrow belts, which have to be strained excessively tight to drive; consequently, the undue pressure and friction on the bearings cause excessive heat, which is conveyed through the spindle to the saw plate. At the same time the belts themselves very much more rapidly deteriorate. Wide single belts are to be preferred to narrow double ones. In American practice the pulleys for driving circular saws are made somewhat larger in diameter and much wider on the face than they are here; consequently, the arc of contract, grip of the belt, and driving power are increased and the slip largely reduced.

Although we are aware that they are considerably wider than most of those in use here, it may be taken as a good and safe rule that pulleys on saw benches carrying saws up to say 4 ft. diameter should have driving pulleys wide enough to carry belts of a width of one-fourth the diameter of the saw, and for saws above 4 ft. in diameter a belt of one-third the diameter of the saw may be used with advantage. Anything extra in the cost of pulleys or belts is rapidly repaid by an increase of work of better quality than can possibly be obtained with narrow belts; at the same time the bearings and belts themselves last longer. With wide belts the necessity of using 'quack' remedies for increasing the grip, which often damages the belt, is done away with; it is necessary, however, to keep the belts pliant, and this can be done by an occasional dressing of mutton fat and beeswax in equal parts. Castor oil is not by any means a bad dressing for leather, and it renders it vermin-proof. In driving saw benches, in fact all wood-working machines, running belts at short centres must be avoided, as it is bad in every respect, and greatly increases the troubles of hot bearings, torn belts &c. above alluded to.

20. English users of circular saws may possibly smile at the idea of a 'frozen' saw, as we are not as a rule blessed with very cold weather in this country, but even a moderate amount of frost has a very distinct effect in many cases on the working of circular saws, especially should they be of thin gauge. In cold countries, or in very cold weather, the effect is so great from the contraction of the plate at its smallest part, i.e. the eye, that the saw will become 'rim bound,' and not turn true till the frost has been taken out of it by friction, or by a dose of hot water.

21. The question of speed is a factor of immense importance in the proper working of circular saws; should they be run either too fast or too slow the result is equally unsatisfactory. In the first case the saw becomes pliant and wavy, and in the latter the work turned out is of bad quality and less of it. For ripping all ordinary kinds of wood a speed of 9,000 ft. per minute at the points of the teeth is now generally recognised as a standard speed in this country. This can, however, in the case of cross cutting, be increased with advantage another 1,000 ft. per minute. In sawing very hard woods the speed of the saw should be somewhat reduced, say about one-fourth. By using thick gauge saws, and therefore wasting wood and power, higher speeds than these may be attained.

We will conclude our remarks on working saw benches with a few gentle hints (some of these may not be new, but we take it they will bear repetition in some establishments we wot of). If a saw bench is used for small and large saws, occasionally the latter will run untrue, from going at too high a speed. For quick rough sawing a swaged set tooth has much to commend it, especially with tough and difficult woods and large saws, as they are much less liable to be strained than if set with a blow or spring set. In sawing difficult woods they are liable to spring away from the saw considerably in the centre of the log; consequently the boards sawn are thicker at each end. To obviate this, instead of sawing in the usual way all from one side, a cut should be taken alternately from each side of the log; this will keep the boards uniform. Should a saw crack in working, to prevent a short crack from extending, drill a small hole at the end of it.

"For ripping purposes most of the filing or saw sharpening should be done on the face or front of the teeth; the backs or tops should be scarcely touched at all. The face of the tooth should never be filed to a fine edge, but a very slight bevel should be left. A round gulleted tooth is less liable to crack than one filed to an angle. In gulleting with emery wheels work with a light pressure, and if necessary go over the teeth several times; if the wheel is forced and the saw plate burnt it is much more liable to fracture. In filing teeth for swage setting make them sufficiently hooked at the points that the swage will readily spread them, also be sure that the points of all the teeth are wider than the rest of the blade; the tops and backs of swage-set teeth should be filed square across. In bending or spring setting always use a gauge; in setting saws with a blow or spring set, care should be taken that the teeth only are set say about one-third of their depth, and that the plate itself is not strained, or it will be found to heat rapidly when in work and run out of truth."

In filing saws, file every alternate tooth from one side of the saw, then reverse it, and file from the other side; never file all the teeth from one side of the saw, and, if it is spring set, set after the same fashion. If in working the saw heats at the rim, and the teeth are of the right shape for the wood and properly sharpened and set, hang or line the saw to lead very slightly out of the wood. If the saw should heat at the centre and the spindle and bearings are cool and in proper order, reverse the above and let the saw lead into the wood a little.

For thin sawing, such as light box work, frame backings, &c., a 'ground-off' saw can be recommended to effect a very considerable saving in wood, and, if carefully sharpened and handled, will do very excellent work.

For very accurate dimension sawing, such as pattern-work, &c., a saw 'ground hollow' on both sides and run without set can be used with advantage, as it will cut extremely true and leave a fine surface.

If timber carriages and rails are used for bringing the wood up to and taking it from the saw, it is important that they be fixed to run exactly true with it. Should the wood be presented to the saw even at a very slight angle, this is multiplied to a considerable extent in a long log, and, if the cut be once commenced, a very considerable leverage must be put upon the saw to keep it anything near the line.

When having saws hammered be sure they are placed in competent hands; we have seen saws that have been hammered by so-called experts that might have been better done by a blacksmith's striker.

For guarding circular saws and preventing accidents we can recommend the following arrangement: Make a shield of sheet steel formed as an arc of a circle, and against the saw; the shield rises before it and rests on the top of it till the cut is completed, when the counterpoise brings it back to its original position. It is important that the driving power be uniform in its speed; if there is much variation, the quality of the work will vary accordingly.

CHAPTER XLIV.

NOTES ON SAW SETTING.

In very few things is there more difference of opinion than in sharpening and setting saws. On the present occasion we propose to discuss briefly the different methods of setting, noticing some of the advantages and disadvantages of each method.

Swage Setting.—Swage setting—called also 'upsetting,' 'jumping,' and 'spreading'—is more largely practised in America than in this country. In this case clearance is obtained for the saw by widening the points of the teeth, usually by means of a crotch punch arranged with two V notches, which are driven on to the points of the teeth by a hammer or weight. The second notch in the punch is rounded, and spreads the teeth points out. We think this plan, especially for circular saws of stout gauge, has much to commend it, more especially if the wood is cross-grained and knotty, as swaged teeth will stand up to the work, while spring-set teeth are apt to dodge the knots. Swaged-set teeth will also stand a quicker feed than spring set, all things being equal; they, however, take more power to drive—probably about 20 per cent.—and unless the setting is carefully done ridge marks are left on the log. We think swage setting is, on the whole, more adapted for soft than hard wood.

It is claimed by the users of swage-set teeth that swaging condenses and hardens the steel at the points of the teeth; but if this is so, with saws correctly tempered it would, we take it, be likely to be detrimental, and cause the points to crumble. Another trouble found in swage setting is the difficulty of getting perfect uniformity of set, without which no saw can be pronounced to be in first-rate cutting condition. Swage setting does not sharpen the teeth of the saw, as some may suppose.

When a saw is set or spread by means of a punch and a blow from a hammer, care should be taken that the points of the teeth only are spread, and that the tooth itself is not bent or strained, and that the blow given and the hammer used are not too heavy. The teeth should be carefully tried with a straight-edge on both sides and points, and be exactly in line. In swage setting, should a tooth point be broken by striking a nail, it can be lengthened slightly by raising the punch or swage when in the act of setting the tooth, and the point of the tooth will be upraised, and, if not too much broken, will take its share of duty with the rest.[1]

To 'spread' set all the teeth as nearly as possible alike with a crotch punch, it is necessary to regulate to a nicety the weight or strength of the blow given by the hammer. In America a tool has been introduced to do this mechanically. It consists, briefly, in mounting the crotch punch on the end of a tube or rod, and arranging a series of movable weights, with holes through them to slide up and down the rod. These weights are allowed to drop on the punch, the strength of the blow being regulated according to the gauge of the saw and the amount of set required. For saws of large diameter and thick gauge spread set can be recommended, as it is very difficult to spring set or bend the teeth of a thick saw with regularity.

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[1] See *Saw Mills, their Arrangement and Management.* By M. Powis Bale.

Spring Setting.—This is perhaps the most general kind of setting, and if regularly and carefully done, answers very well; the teeth, however, have a constant tendency to assume their original position. Saw teeth should not, under any circumstances, be set without a gauge, as it is a wasteful and stupid plan, producing rough work, and more rapidly wearing out the teeth which happen to be overset. In practice it will be found that a saw perfectly set will work much freer, cut smoother, and, at the same time, will waste less wood than an imperfectly set one; less set is also required on a truly and equally set saw to effect the desired clearance.

Several good mechanical saw sets, combined with gauges, are now made, and so arranged that when they are fixed to any desired set it is impossible to overset a tooth; consequently, the teeth are all set exactly alike, and if they are equal in length, each tooth gets its fair share of work, the friction of working and waste of wood being reduced to a minimum. In working, it is found that the teeth of a saw wear at the side of the points, and if some teeth have more set than others, these are unduly strained, and, from the severe and uneven friction, are often heated, and are inclined to buckle and run from the line. In using spring set, it is necessary to somewhat overset the saw, to compensate for the tendency of the teeth, especially when worn or dull, to spring back to their original position.

We have recently seen a very neat form of American tool for spring setting by means of a cam-lever, by which a very even set may be obtained without unduly straining the saw teeth. The operator stands behind the saw, and the set is attached to the teeth by placing a bed die on the point of the tooth to be set so that the point will project beyond the die about one-sixteenth of an inch; the cam-lever is then brought down to a stop on the cam, at the same time bending the teeth towards the latter. A four-point gauge is fitted to the lever, and it can be adjusted to any amount of set desired by means of a thumbscrew. It is claimed as an advantage of this arrangement that the bending power is exercised on the tooth between two bed bearings, so that the operator has only to bear down on the cam-lever, and the more power he applies the tighter he fastens the set to the saw, and at the same time the bend is a curve and not an angle, and that, therefore, the saw teeth are less liable to fracture.

If a saw is allowed to get dull it will spring from the work, and increased power will be required to force it through the wood.

Hammer Setting.—The third system of setting we have to notice is hammer setting. The old-fashioned way of doing this was with a punch and a block of wood, and a very brutal way it was, as it strained the saw plate, and sometimes broke the teeth; at the same time it was impossible to set the teeth to one uniform set, consequently the timber was scored and much power consumed unnecessarily. If carefully and judiciously done, hammer-set saws will stand up well to their work. The best plan with which we are acquainted is to mount the saw horizontally on a conical centre and allow the teeth to rest on an adjustable steel die made with a bevelled edge turned eccentric, so as to allow of the right proportion of set for teeth of various sizes. With this arrangement any desired amount of uniform set can be given to the teeth without unduly straining them or the saw plate. Hammer setting is a fair test as to the quality of the saw, as the teeth may crack or fracture if the steel is burnt or of too hard a temper, or bend readily if too soft.

In conclusion, it must be borne in mind that, whatever kind of setting is employed, for successful and economical working *absolute uniformity* is imperatively necessary. If this is not secured, the work turned out is of inferior quality, and wood and power are wasted. It should also be remembered that setting does not increase the cutting power of a saw, as a saw will cut faster with little or no set provided the nature of the wood will allow it to pass through without binding. The amount of set required, therefore, should be carefully judged by the sawyer, and no more set employed than is absolutely necessary. For instance, in sawing wet wood a sharp saw and a fair amount of set are required, whilst for hard, knotty wood very little set should be used.

CHAPTER XLV.

NOTES ON STICKING HIGH-CLASS MOULDINGS.

We think it will be generally admitted that the production of really high-class mouldings—that require little or no hand-finishing—is the exception and not the rule. This arises from a variety of circumstances, such as (1) bad wood, (2) poorly constructed machines, (3) bad adjustment of cutters, (4) improper speed, (5) insufficient foundations, &c.

(1) It goes without saying that high-class mouldings cannot be produced without good material; we need only remark, therefore, that the wood should be thoroughly sound and well-seasoned.

(2) The construction of the machine is also a very important factor, and it may not be out of place to extend our remarks thereon to some length. The two classes of machines generally used—not including vertical spindle or shaping machines—are: (1) centre-feed machines, (2) overhanging-spindle machines. For light purposes, overhanging-spindle machines are extremely handy and useful, but for large and high-class work, centre-feed machines are to be preferred, and our remarks on construction will therefore refer chiefly to this class.

Construction of Centre-feed Moulding and Planing Machine.

After a lengthened experience, it has been found that the box or solid framing is the best form to adopt for the main frame of the machine. The reason for this is not far to seek, as in moulding and planing wood very high speeds are necessary, and various strains are set up, and to absorb these and their consequent vibrations a considerable weight of metal is necessary, and this metal is much more effective when in the form of a single casting than when put together in sections. Box-framing is slightly higher in first cost, but this is more than counterbalanced by its increased strength and resistance to stress, by economy of material in ratio to strength, and by its greater neatness of design. The cutter spindles should be supported by bearings of ample area, and these should, as far as possible, be made adjustable for wear and end play, more especially the bearings, which are subject to considerable belt tension. The question of lubrication must be carefully attended to, and the bearings guarded from dust.

To secure a constant and even feed, and prevent the slipping of the wood, it is important that all the feed gearing be expansively geared up together. If the feed-rollers are geared separately, the wood is apt to slip, particularly if difficult to work. In the best class of machines, the intermediate pinions are made of steel or gun-metal. As a sufficiently long belt may be obtained, and as, at the same time, it economises space, it has been found convenient to place the countershaft working the feed gear within the framing of the machine. This should be fitted with four-speeded cones, so as to give varying speeds of feed of, say, from 10 ft. to 60 ft. per minute. The countershaft working the cutter spindle should be placed, say, 15 ft. away at least, as running belts at short centres is to be condemned from every point of view. The cutter-block and spindle should be made of steel, as they are thus stiffer in work and can be made of somewhat smaller section than with wrought iron. The cutters should be fastened to the blocks by dove-tail-headed bolts, sliding in suitable grooves. These should be made of best Swedish iron, and be very carefully fitted. Irons should never be fastened by means of studs tapped into the blocks, as the method is both dangerous and uncertain.

A very considerable difference of opinion seems to exist amongst makers as to the best position in the machine in which to place the vertical spindles or side cutters; some fit them at the end of the machine, to act on the wood after it has passed the top and bottom cutters; others put them in the centre of the machine, between these cutters. The writer is in favour of the latter plan, as the wood is then directly under the action of the holding-down apparatus, and there is less liability of its jarring when under the operation of the cutters. The plan of placing the vertical spindles at the end of the machine renders them rather more accessible for adjustment; but, in all cases, holding-down or pressure apparatus should be fitted close up to all the blocks.

It is of the utmost importance that the cutters should bed evenly well on the block, and, to secure this, knives are made sometimes very slightly concave from the cutting to the back edge, so that when the nuts are tightened they spring slightly, and bear on the whole surface of the block alike. Cutters made slightly thicker at the back than at the cutting edge are preferred, as they are less likely to slip forward from the high speed and centrifugal force set up. It is important that the iron round the slot holes be true, and that all the hollows and smithing marks be ground out, so that the nuts and washers have a perfectly true bed to rest on.

But, given all this, and a good and true block, we sometimes find irons flying, and shifting on their seats. This may arise from the bolts not being tightened enough, or from being tightened too much, this latter being a very fruitful cause. In order to secure the bolts, as he thinks properly, an inexperienced or careless workman is apt to use a powerful wrench, with sometimes a pipe at the end of it, to tighten them up, —the thread of the bolt consequently becomes damaged, the pitch being stretched and bulged and made coarser. One of the reasons why there is sometimes a difficulty in bedding the nuts, is that the threads are often allowed to get dry and filled with grit. Irons may be prevented from slipping by bedding them on several thicknesses of brown paper or thin leather.

In machines where movable blocks are employed, it is of the utmost importance that the spindle holes are perfectly true and fit the spindle tight, and are exactly parallel with the cutter face: this is not altogether an easy matter with long blocks, as they are apt to get slightly oval. When the cutter-block is revolving at a high speed, this will allow it to spring sufficiently to damage the output, and is one of the causes of inefficient working very difficult to detect. Light blocks require balancing as much as heavy. If movable blocks are used, they should in all cases be planed by the makers after being fixed on their spindles.

Making and Tempering Moulding Irons.

It need hardly be said the steel used for cutters should be of the very highest possible quality, combining in its nature, as far as may be, toughness with hardness. It must be admitted that there is a considerable amount of art in forging and tempering cutters successfully, as, owing to the varying amount of carbon contained in different samples of steel, the amount of tempering varies accordingly, and the exact temper necessary can only be ascertained by one or more trials; the folly, therefore, of treating all kinds of steel alike, which is sometimes done by the workman, is at once apparent. It may be taken as a rule that if it is necessary to heat the steel so hot that when it is annealed it appears coarser in the grain than the piece from which it was cut, it may safely be concluded that it is of too low a temper for the required work, and a steel of a higher temper should be selected. A steel cutter, when properly tempered and suited to the work in hand, should always be of a finer grain than the piece from which it was cut.

Moulding irons may be roughed out and ground down to something near the size by means of small profile grindstones or emery wheels, and when filed to the exact profile and tempered before using, a cutting edge should be put on them by means of a slip of Turkey or other good oil-stone. When the irons are of simple form, to avoid softening and rehardening, the steel may be ground to the shape by the series of small grindstones spoken of, the peripheries of which are turned up to suit the rounds and hollows of the mouldings. We have found Bilston grindstones answer very well.

With the object of preventing the constant change of profile when sharpening moulding irons, of the ordinary construction, in which the profile of the moulding is formed on the edge of the steel, and a bevel ground backwards from it, some makers mill the form of the moulding into the face of the cutter itself, as if sharpened to the proper bevel; it thus always retains its true form. This form of profile may be secured for vertical spindles, no matter how badly the cutters are sharpened, by using solid circular cutters. These are made from one piece of steel, in form something like a deep saucer. The periphery of the steel is shaped to the profile of the desired moulding, and has several openings which are sharpened towards the centre, and present as many cutting edges to the wood.

In forging or tempering moulding irons it is important that they should be heated as evenly as possible. If one part of the cutter is thinner than the other, care must be taken that the thin part does not heat more rapidly than the rest, or it may be 'burnt,' and break off at the cutting edge whilst in work. In heating cutters for tempering, they should be repeatedly turned over in the fire, and withdrawn from it now and then. If the cutting edge is heating too rapidly, it should be pushed through the fire into cooler coals. If there are a number of members in the same moulding, great care should be exercised in tempering them as nearly alike as possible, or they will vary in wear, and the profile of the moulding be altered accordingly. It is important in tempering that there should be a gradual shading of colour. If there is a distinct line between the colours towards the edge of the cutter it will probably chip at this line. The point to aim at is to have the edge of the cutter tolerably hard, and this hardness to be gradually reduced the farther you go from the cutting-edge, and the softer metal at the back will be found to strengthen and support it.

The process of tempering should be gradual, as the steel becomes toughened and less liable to fracture by slow heating and gradual softening than if the process be performed abruptly. When the proper heat has been reached, the tool should be removed from the fire and not allowed to 'soak' with the blast-off, as is sometimes done. Bear in mind, in forging, welding, or tempering steel tools, that an excess of heat over what is absolutely necessary is detrimental, as it opens and makes the grain of the steel coarse. If a tough temper is required, the cooling, or letting down, should be as slow as possible. The right temper colour varies with the steel and the hardness required. Templeton gives the following degrees of heat: Chipping chisels, planing irons, hatchets, and other percussive tools, 500 deg. to 520 deg., light straw colour, a brown yellow, or yellow slightly tinged with purple; 530 deg., light purple. As the colours appear and change slowly, ample time is afforded to see when the cutter should be at once dipped and withdrawn several times; as this has a greater tendency to toughen the steel than if it is plunged into the water and allowed to remain until quite cold. A number of more or less reliable mixtures are used for tempering. We have found the following answer very well: Take 4 parts of powdered yellow rosin, and 2 parts of train oil, and carefully mix them, and add one part of heated tallow. The object to be hardened is dipped in this hot, and allowed to remain in it till quite cold. Without having previously cleaned it, the steel is again put into the fire, and then cooled in boiled water in the usual way.

Speed of Cutters.

In turning out high-class mouldings, the question of the speed of cutters is of great moment; exigencies of space prevent us here going into the question at length. In a thoroughly well constructed and equipped machine, a speed of 4,000 revolutions per minute may be taken as a standard.

Balancing the Cutters.

Another matter of the extremest importance in securing highly finished mouldings is the *exact* balancing of the cutters. These should not only be of the same exact weight and overhang, but all cutters must be made to agree in their corresponding members to the greatest possible nicety. The importance of this will be readily recognised when we consider the high velocity at which they have to run; consequently any inequality is enormously multiplied by the centrifugal force set up, the result being transferred to the wood in the shape of jars and markings. When new cutters are put on, they should be put exactly in balance and kept so. In working elaborate mouldings, it is difficult to keep both irons alike, and one plan often pursued by the operator is to use an iron for each member of the moulding, and to balance the irons with beams and scales; and when the iron projects, say 1½ in., to put on a rectangular washer. In working vertical spindle machines, some operators will use one iron only, with a blank on the other side of the block to balance.

As already mentioned, in accurately balancing cutters, not only should their specific weights agree—which is a matter of little difficulty, as it can be determined with a common pair of scales—but the weights of the cutters should agree in their corresponding parts. This cannot be ascertained accurately without the aid of a proportional cutter balancing machine, and several of these have now been introduced with very satisfactory results. In the best of these machines the cutters can be tried one against another in every position, and if any excess of weight appears in any of them at any point in the backs, fronts, or edges, it can be detected and remedied.

Driving-belts.

All driving-pulleys should be of ample width for the power they have to transmit, without straining the belt, and, therefore, cutting out the bearings. Wide single belts are preferable to double, and the best leather to other material. It is important that the driving-belts are kept as pliable as possible. This is not a very easy matter in a sawmill, owing to the very fine dust constantly floating about and filling up the pores of the leather. A mixture of mutton fat and beeswax in equal parts will be found a capital dressing, and will not injure the belt. An application of tanner's dubbin for leather, and of linseed-oil varnish for cotton belts, can also be recommended. Castor oil is also an excellent dressing for leather, and, at the same time, it renders it vermin-proof. It should be mixed, say, half and half, with tallow or oil. For preserving or recovering leather belts from mould, pyroligneous acid may be used. The belts should be thoroughly stretched and carefully made. Cemented joints are to be preferred to others, as they run smoother over the pulleys.

CHAPTER XLVI.

THE BEST ENGINE FOR A SAW MILL.

ALMOST every type of engine is made to do duty in a saw mill, and as many of them are utterly unsuited to the work the result is often anything but satisfactory both on the score of economy and effective working.

Owing to the severe and variable duty required of a saw-mill engine, it should be of especially strong and substantial construction, and able to command a uniform speed under suddenly applied loads.

After a lengthened experience the author is of opinion that the best form of engine for driving wood-working machinery—except under special circumstances—is a long stroke horizontal high pressure, either compounded or with a condenser, or both. Some years ago, in the present volume, the author, in writing on some points to be desired in a saw-mill engine, mentioned the following, and as his views in this respect have not altered, it may not be out of place to repeat them.

1. A stroke of twice the diameter of the cylinder; 2. either compounded or with a condenser, or both; 3. or an automatic expansion slide, controlled by powerful and sensitive governor gear; 4. a steam-jacketed and lagged cylinder; 5. short steam ways;

6. ample bearing surfaces, well fitted and lubricated, and an efficient method of packing; 7. large cylinder area per h.p.; 8. a fly-wheel of large diameter and extra heavy section; 9. a moderate piston speed.

Speaking generally, in selecting an engine the chief points to be borne in mind are: 1. the nature of the work it has to do; 2. the speed and power required; 3. the cost of fuel; and 4. if under skilled management. In a saw-mill if the fuel be plentiful, and the management unskilled, as is often the case in isolated countries, a plain slide-valve engine would possibly suit better than a first-class one with expansion gear, condenser, &c., the loss of fuel being partly compensated for by the greater freedom from breakdowns. In this case, the engine should be arranged to cut off steam tolerably early and expand it for the rest of the stroke, and powerful governor gear should be employed. On the other hand, in establishments where large power is required and skilled management is attainable, the most advanced form of engine is in the end by far the cheapest. In cases where fuel is dear, a good compound condensing engine can be used with advantage: but it cannot be too often repeated that, where extreme economy is required, a skilled engine driver is an absolute necessity. If the steam pressure by which an engine is worked would be likely to vary considerably, and the load likewise vary, to secure steady and even running the engine should be fitted with valve gear having a considerable range of cut-off, combined with a powerful and sensitive governor.

In selecting an engine a full detailed specification, giving sizes and materials, should be obtained from the maker, with his guarantee as to horse-power—brake horse-power, if possible—the engine will give out at a certain steam pressure, and that it will work at its full speed and power without excessive vibration.

See that the bed-plate and frame and working details of the engine are of ample strength, also that the cylinder has sufficient metal to allow of its being rebored several times, that the steam passages are short, that the sliding and bearing surfaces are ample, and that they are adjustable for wear. The author prefers a medium piston speed—say 500 ft. per minute—to higher speeds, as he has found the cylinders of large horizontal engines run at high speeds rapidly wear hollow.

An engine of ample, but not excessive, power for the work to be done should be selected, as too large an engine is as wasteful of steam as too small a one.

For saw-mill work, the author prefers the bed-plate of the engine to be on the double girder box plan, and to extend beyond the cylinder, which should be mounted on it, as this is undoubtedly the best form to resist heavy working strains. If a pair of engines are used, it will be found well to have one large fly-wheel for the two engines, placing it between them, with an extra pulley for driving the main shafting. Crankshaft to be fitted with an outside bearing. Connecting-rod ends to be made adjustable for wear, and fitted with straps and keys. Engine to be fitted with wide double motion bars and blocks, and made adjustable for wear. The bars should have oil recesses and grit cavities. Stop and starting valve to be provided, and so arranged that access can be had to the throttle valve without disturbing the steam pipe. The steam passages should be large, short, and direct, and the clearance in cylinder as small as possible.

For driving wood-working machinery, after repeated trials, the author is distinctly in favour of an engine with a long stroke, as it permits a higher piston speed without excessive vibration and wear and tear, and the steam can be expanded with greater facility. The steam ports should be as short as possible. This can be secured by dividing the slide valves, and placing them at each end of the steam chest; and a high speed sensitive governor should be arranged to act on an equilibrium double-beat throttle valve, or on expansion gear. The exhaust should be of ample size, to admit of the instant escape of the steam and avoid back pressure. In crowded spaces it is sometimes necessary to use a vertical engine; these can be compounded with advantage, and although necessarily of shorter stroke, they can be worked with less wear to the piston, cylinder, glands &c. than a horizontal engine, the wear being distributed, whilst in a horizontal engine the cylinder wears oval.

Arrangements should be made for the continuous drainage of the cylinder, and it should be fitted with a good sight-feed lubricator, which is a distinct improvement over ordinary grease cups, as with these latter the piston may be running perfectly dry, and the cylinder may be scored and the rings cut out before the attendant is aware of it. A very considerable economy in oil is also effected by the use of a sight-feed lubricator, as it can be adjusted to supply the minimum amount of oil to keep the cylinder properly lubricated. On the other hand, the old-fashioned grease cup floods the cylinder with oil for a short time, and this being rapidly cleared away by the strokes of the piston, the cylinder is left comparatively dry in a little time.

Compound engines have of late years come considerably into use, and are more economical than single-cylinder engines. This arises chiefly from the fact that much higher pressures of steam can be expanded with greater advantage in two cylinders than in one, and without the considerable loss from condensation which arises in a single cylinder when the steam is cut off very early in the stroke. Again, if a considerable range of expansion be attempted in a single cylinder, and the cut-off is very early, the strain on the working parts is great, necessitating excessive weight and strength in the engine. In the case of compound cylinders, however, this strain is distributed.

In single cylinders, if large expansion be attempted, the steam condensation is excessive and becomes a serious matter. Compound engines will work more steadily and with less friction and vibration, consequently the general details of the engines may be made lighter. Where a sufficiency of water is obtainable, a condenser can be fitted to an engine with considerable advantage, as in this case, instead of being exhausted into the open air or water tank after each stroke of the piston, the steam passes through the exhaust port into the condenser, and coming in contact with the water, which is in constant circulation therein, is itself immediately condensed or reduced to water. In working the condenser an air pump is employed, which keeps up a vacuum and relieves the piston from back pressure, thus increasing the effective power of the engine. The water made hot by the condensation of the steam is again used to feed the boiler, hence a second saving arises.

A simple and convenient arrangement for working the air-pump for a condenser is to prolong the engine piston-rod through the back cylinder cover. The air-pump should be double acting, and the valves arranged so as to give ready access for adjustment and repairs. The engine-bed should be prolonged and the condenser mounted on it, so as to secure perfect alignment. The author has found pump valves of india rubber, with gun-metal seats, guards, and bolts, work very well. If there is no overhead tank for the injection water, sluice valves will be found most useful for starting the engine.

Automatic expansion gear is especially useful in a saw mill, and with varying loads effects a considerable saving, as the admission of the steam is regulated according to the speed or load on the engine. The gears of Corliss & Proel have proved themselves very effective.

Another very satisfactory arrangement of automatic expansion gear is the Ruston. In this the cut-off valve is made multiple-ported to give free admission of the steam, and is driven by a radius rod, the free end of which is moved up or down in an oscillating slot-link, which is driven by a separate eccentric, the precise position of the rod being determined by the governor. As the speed of the engine increases and the governor balls rise, the travel of the expansion valve is reduced, and the steam is cut off earlier; should the engine run more slowly, the contrary occurs. The range of cut-off is from a fraction up to half stroke.

A further advantage arising from the use of automatic expansion gear is that the steam is always delivered to the cylinder at the highest available pressure, whilst in the case of an ordinary slide-valve engine where the cut-off of the valve is always positive, the admission of the steam is governed by means of a throttle valve, the action of which 'wire draws,' and reduces the pressure of the steam. With efficient expansion gear the amount of steam required to do the work on hand at the moment is practically measured at every stroke of the engine, and no more is used than is required, and this in turn is fully exhausted of its energy by expansion.

Owing to the constant and great variation of the load in a saw mill, it is important that a governor be fitted sufficiently powerful to keep the engine perfectly under control, and the speed uniform. Various forms of high-speed governors have come into use, and several of these have proved themselves both sensitive and quiet in action, and are to be preferred to the older-fashioned type.

For the guidance of readers we append a short specification of a high-class engine, well adapted for saw-mill work: One improved horizontal compound tandem condensing engine to indicate 310 horse-power mounted on double girder box plate, planed on face; high-pressure cylinder, 18 in. diameter; low-pressure cylinder, 34 in. diameter; stroke of pistons, 36 in.; number of revolutions per minute, 90; diameter of vertical air pump, 20 in.; stroke of vertical air pump, 18 in.: diameter of horizontal air pump, 14 in.; diameter of crank shaft, 10 in., made of best fagotted scrap iron; diameter of fly-wheel, 18 ft.; width of face of fly-wheel, 28 in.; diameter of stop valve of high-pressure cylinder, 5 in.

CHAPTER XLVII.

THE BEST BOILER FOR A SAW MILL.

EVERY possible type of boiler has been made to do duty in a saw mill, and it need hardly be said that many of these are quite unsuited for the work they have to do, consequently the economical result is unsatisfactory, and, taking the whole world over, boiler explosions are more frequent in saw mills than in any other class of manufactory. Most types of boiler possess some advantages and disadvantages; in selecting one, however, the chief points to be borne in mind are: 1. the quality of the feed water; 2. the quality and nature of the fuel; 3. if for temporary or permanent duty. It may be as well also to mention a few of the points to be desired in a steam boiler.[1] 1. A boiler of a design that can be readily inspected, cleaned, or repaired. 2. A thorough circulation of the water through the boiler. 3. A large furnace or combustion chamber. 4. A sufficiency of water and steam space to avoid sudden fluctuations in the water level or steam pressure. 5. A large margin of strength over working pressure. 6. Stays, ends, strengthening rings &c., arranged with an allowance for expansion. 7. Ample heating surface, with no joints or rivet heads exposed to the direct action of the fire. 8. Boiler to be properly fixed and equipped with a full supply of fittings of the best type. 9. Chimney stack to be correctly proportioned to the boiler and to the fuel to be burnt. 10. Boiler to be of a type suitable to the feed-water and fuel used, and to be made of first-class materials, and with good workmanship.

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[1] *A Handbook for Steam Users.* By M. Powis Bale. (Longmans & Co.)

In saw mills the fuel used is usually small coal mixed with wood waste, which gives out a fierce fire, and should have a boiler with considerable grate surface to consume it economically. The locomotive type of boiler has the advantage of raising steam quickly; it can be safely worked at a high pressure, and requires little foundation; on the other hand it is unsuited for burning inferior fuel without a forced draught, and a specially large fire-box is necessary. With the fuel usually used in a saw mill the plates and tube ends are more easily burnt than in a plainer boiler, more particularly if incrustation is allowed to accumulate; in point of fact, should the feed water be bad, a locomotive boiler should never be used, unless special means be taken to purify the water before it enters the boiler. When burning small bituminous coal under ordinary conditions, locomotive boilers have a tendency to produce smoke; this can, however, be modified considerably by the employment of a sufficient height of chimney to induce a quick draught, a fire-brick arch, and careful and even firing.

Water-tube boilers have been introduced into saw mills in this country to a limited extent, and it is claimed for them that they are both safe and economical; there appears to be little doubt, however, that some of them generate wetter steam than a good Lancashire boiler, and with inferior fuel, they produce much smoke. Moreover, having many caps and joints, they are not so readily kept in order.

On the other hand, it is claimed by the makers of water-tube boilers that they possess various advantages over other boilers, such as occupying less space, greater heating surface, less fuel used, perfect water circulation, sectional divisions, preventing disastrous explosions, &c. It must be admitted that many of these boilers are in use in America, and are spoken well of, and the smoke not complained about; but this can be explained to a great extent by the fact that the fuel used consists largely of anthracite coal, which is practically smokeless. It must also be conceded that where accidents or explosions occur with locomotive or tubular boilers they are usually not so disastrous as those with Lancashire and Cornish boilers, and higher pressures can be worked with safety.

A combination of the double-flued or Lancashire boiler and tubular boiler has lately come into extended use for driving electric lighting plant, &c., and where the feed water is fairly pure can undoubtedly be recommended, as they are found to be rapid steam raisers, and economical in the consumption of fuel. The boiler consists of an ordinary internally fired Lancashire boiler, with cross tubes, but, in addition, a series of horizontal tubes run the full length of the shell. It is claimed for this boiler that it has a considerably larger heating surface than a Lancashire boiler, a medium water capacity, occupies a minimum of space, small area of brickwork, and has a fair amount of steam space.

In countries or districts where wood waste is the only fuel, externally fired tubular boilers are largely used; in this case the boiler is mounted over a brick furnace, in which the wood is burnt, the heat passing under the boiler and back through brick flues on each side, and up the chimney. In using these boilers especial care should be taken to keep them entirely free from incrustation. In America, an under-fired cylindrical boiler, with return tubes of 3 in. or 4 in. diameter, is used considerably. These are low in first cost, and when arranged with a wide under-furnace and brick flues are said to be fairly economical.

Under-fired boilers are not popular in this country, and there is little doubt under-firing considerably strains the seams &c. of a boiler, especially if a long one.

Except for small power and in crowded situations, vertical boilers cannot be recommended for saw-mill work, as they are apt to prime and produce wet steam. This arises from the water and steam space being small, consequently wet steam is drawn into the steam pipe to a greater or less extent at each stroke of the engine. High-speed engines mitigate this evil somewhat, but they themselves are unsuitable for saw-mills.

Taking the advantages and disadvantages of the different types of boilers into consideration, the author, after a lengthened experience, is of opinion that for a permanent saw mill of any magnitude no boiler is superior to a well-designed and equipped Lancashire boiler, or, if the feed water be good, a Lancashire boiler fitted with cross-tubes and a series of horizontal tubes above the internal flues.

Amongst the disadvantages of Lancashire and Cornish boilers may be mentioned their cost—when the expensive nature of their fixing is borne in mind—for a given horse-power and the increased length of time necessary to get up steam as compared with a locomotive or tubular boiler. On the other hand they possess several important advantages in that they can be readily cleaned and repaired—a matter of great moment in cases where the feed water is bad—and inferior fuel, wood, waste &c. can be burnt in them without much trouble. If carefully fixed and fired, a Lancashire boiler can also be worked with comparatively little smoke. A well-designed Lancashire boiler has a much larger water and steam space than is usually found in locomotive or water-tube boilers, consequently when any special or sudden demand is made for steam it can usually be supplied without much inconvenience or fall in pressure. As already mentioned, the smoke nuisance may—in a Lancashire or Cornish boiler—be reduced to a minimum, as the grate surface is of considerable length, and by 'coking' the fresh fuel at the furnace front the air admitted has time to rise in temperature and mix with the gases evolved before it reaches the bridge, and combustion is completed here and in the flue beyond. It may be as well to remark here that the employment of a fire-clay bridge or arch can be recommended both in Lancashire and locomotive boilers.

Supposing for the time being that a Lancashire boiler be selected, it may not be out of place to briefly discuss some of the points to be desired in its construction, as, although great improvements have taken place of late years in the manufacture of steam boilers,

boilers of inferior construction and equipment are still made.

In selecting a boiler, a full detailed specification of sizes, materials, workmanship, and fittings should in all cases be obtained from the manufacturer, with the brands of the boiler-plates stated, and should these not be of well-established repute, a guarantee as to the tensile strength, ductility, and elasticity of the plates employed should be requested.

As regards materials, mild steel plates (Siemens-Martin open-hearth process) are generally admitted to be the best and most reliable that can be used at present. In the best boilers the plates are specified to have a tensile strength of not less than 26 tons per square inch. The edges of the plates should in all cases be planed, and the seams are best made with butt joints and double butt-straps, which are the strongest and most reliable form. All rivet-holes should be drilled in position when possible, and the rivets closed by machine; in point of fact, materials, workmanship, and fittings should all be of the highest class. The difference in price between a good and a bad boiler is not great, and a user should never be tempted to purchase a low-priced one, as he will probably find it a very costly economy.

For the guidance of our readers we append a short specification of a 30 horse-power Lancashire boiler suitable for saw-mill work:—

Material.—The boiler to be made throughout of the best selected mild steel plates adapted for boiler work, the tensile strength of which shall not be less than 26 tons per inch. Brands to be marked thereon.

Shell.—Length of boiler, 28 ft.; diameter, 6 ft. 6 in.; diameter of flues, 2 ft. 3 in.; thickness of circular plates, ½ in.: thickness of end plates, ⅝ in.; thickness of flue plates, ⅝ in. The longitudinal seams to be double riveted, and to break joint not less than 12 in.

All rivets to be subjected to a pressure of 25 tons, and all rivet-holes to be drilled in position where possible.

All rivets to be closed as far as possible by machine.

Ends of boiler to be flanged to shell, and supported by gusset staps riveted to double-angle rings at each end. All plate edges to be planed and carefully caulked inside and outside. The edges of end plates and angle-rings to be turned, and the holes for flues to be cut by machine.

Flues.—The plates to be welded longitudinally and joined by Adamson's flanged seams or other approved method for resisting collapse.

Each flue to be fitted with four Galloway cross-tubes, the first to be placed vertically in the fourth belt of plates.

Fittings.—One steel double-flanged manhole double riveted to top of boiler outside, and strengthened with stiffening piece and ring inside fitted with strong manhole cover, bolts, &c., All branches for receiving mountings to be faced. Fire-doors to be fitted with air-slides. Fire-box and bars to be arranged for burning sawdust, shavings &c. as well as coke and coal. Two sets fire-bars with bearers, dead plates, damper, damper frame chains and weights. Suitable flue doors and frames and floor-plates, and frame for blow-off pit.

Mountings.—One steam stop valve, valve of gun metal; two dead weight safety valves of ample area; one low-water alarm; one combined feed-regulating and back-pressure valve; one gun-metal asbestos-packed blow-off cock; two sets of asbestos-packed water-gauge fittings; one 7 in. steam-pressure gauge, graduated to 180 lbs., fitted with siphon and tap; two fusible plugs to be placed in crown of furnaces; one perforated anti-priming pipe; two asbestos-packed water-gauge cocks.

The boiler to be tested by hydraulic pressure to double the average working pressure for which the boiler is intended, and whole completed to the satisfaction of Mr. ——. The author in all cases recommends the use of a good feed-water heater in conjunction with the boiler, as there is little doubt a distinct economy is effected by raising the water to a high temperature before it enters the boiler; at the same time it precipitates many of the impurities contained in it, and prevents them entering the boiler. Feed-water heaters have not been hitherto as largely used as they should be, but as skilled boiler management becomes more and more necessary on account of economy they should be rapidly introduced.

Complicated forms of heaters should be avoided; they should be capable of being readily cleaned and examined, and any tubes employed should be so arranged that they have freedom to expand and contract, and the water should have a rapid circulation.

Whatever form of feed-water is employed, it is important that provision be made to prevent any back pressure on the engine. This can be done by fitting a relief valve so arranged that whenever the pressure of the exhaust exceeds that of the atmosphere to any appreciable extent, the valve opens a communication between the inlet and outlet.